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# TELESCOPE



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FEBRUARY, 1957

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Sky and TELESCOPE

CHARLES A. FEDERER, JR., *Editor*
JOSEPH ASHBROOK, *Technical Editor*



Vol. XVI, No. 4 FEBRUARY, 1957

## CONTENTS

**COVER**: The antenna of the Ohio State University radio telescope, used to make the 1.2-meter radio map of the sky on page 160 of this issue. It consists of 96 helices, mounted on a massive steel framework 160 feet long, which is pivoted on a horizontal east-west axis. The antenna can be pointed to any declination between −40° and +90°; like a meridian transit instrument, it sweeps the sky as the earth rotates. Ohio State University photograph.



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The principal articles are indexed in THE READERS' GUIDE TO PERIODICAL LITERATURE.

# Volunteers Needed for Auroral Observations

THE International Geophysical Year, from July 1, 1957, to January 1, 1959, will be an intensive co-operative study of a wide range of geophysical problems. Simultaneous observations of solar and terrestrial phenomena will be made from every continent by scientists of more than 40 nations.

One of these IGY programs in which volunteer observers can give extremely valuable assistance is the study of the aurora. An extensive attack on this phenomenon will aid in filling the large gaps in our knowledge, and will help explain the aurora's close relation to ionospheric disturbances, magnetic storms, polar radio blackouts, and possibly weather changes.

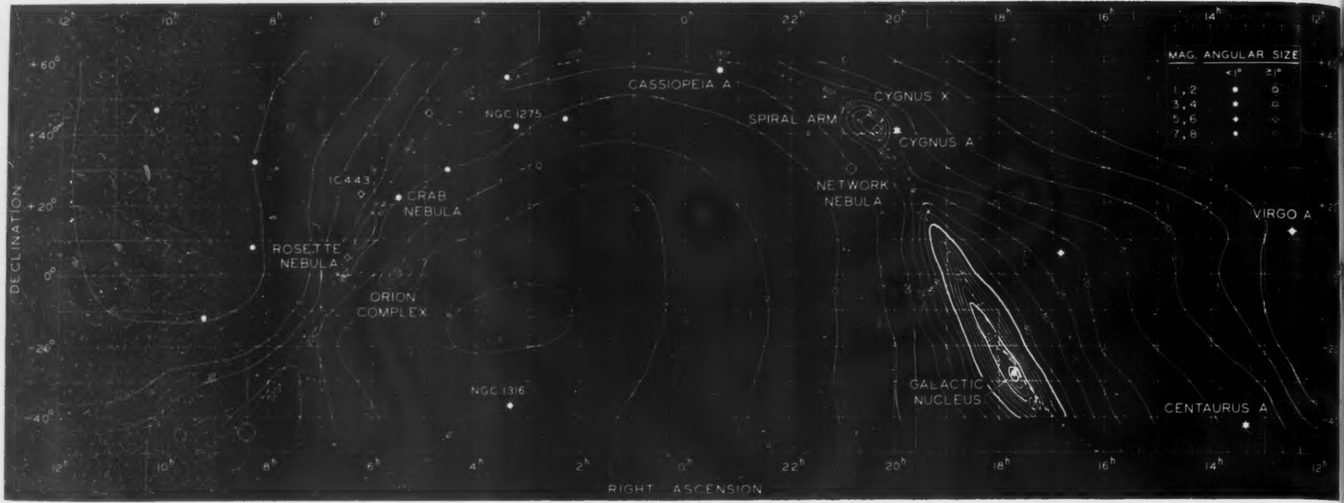
The aurora is caused by bombardment of the earth's atmosphere by particles emitted from disturbed regions on the sun; it is visible by night in a variety of forms: arcs, rays, pulsating forms, and flames. The auroral light generally is so weak that some of its aspects cannot be photographed, and thus visual observations are needed.

In an integrated North American observing program, 29 all-sky cameras will photograph the heavens at one-minute intervals, recording auroral detail within 200 miles of each station. Twelve spectrographs will be used to observe the auroral spectrum. Specialized radar stations in Alaska and elsewhere will study the relation between the visible aurora and regions in the ionosphere reflecting high-frequency radio signals. Scanning spectrometers and radio-wave absorption measurements will give further data. At other stations, photometric studies will be made of the faint night glow visible only on nights of no aurora.

Also sharing in the North American program, about 100 U. S. Weather Bureau stations will make brief hourly reports on the aurora seen along the meridian. These will provide a continuing patrol, whose results will assist in the compilation of synoptic maps showing the geographical location of auroras from hour to hour. Data of this sort are of great statistical value.

But many weather stations are not ideally located for auroral observations, and their personnel have other duties. Volunteer observers are needed to give more detailed information more frequently. If there are enough volunteers, some will surely be in clear areas at times when most of the weather stations are clouded out. Even brief observations can be very valuable in completing the over-

*(Continued on page 161)*




**A radio map of the sky made at a wave length of 1.2 meters with the radio telescope of Ohio State University pictured on the front cover. The contours show the radio brightness of the sky background, while the small circles indicate discrete sources (or radio stars). The magnitude scale for these sources is analogous to the one used for stars observed optically. The solid dots indicate sources less than one degree in diameter; the sizes of the open circles show the approximate angular extent of larger sources. The co-ordinates of the chart are for epoch 1950.0. To avoid confusion in the region of the galactic center, contours for intensities 50, 100, and 150 have been made heavy; that for 150 encloses the discrete source marked "Galactic Nucleus." Ohio State University chart.**

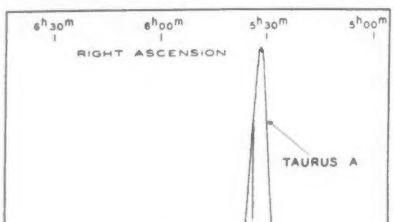
# A Radio Map of the Sky at 1.2 Meters


H. C. Ko and J. D. Kraus, *Ohio State University*


STAR CHARTS are familiar to all astronomers, but radio maps of the sky are relatively new. These show how the heavens would appear if our eyes were sensitive to radio waves instead of light. The radio sky bears some resemblance to the visual sky since the Milky Way is a feature of both, and in fact completely dominates the former. Here the resemblance ends, since no visible star appears on the radio map, and the radio sources that do appear are either of unknown origin or correspond to very faint optical objects of unusual kinds.

Early radio maps of parts of the sky were published by Grote Reber in his article, "Cosmic Static," in the November, 1944, issue of the *Astrophysical Journal*. Reber's charts had only a few contours, but these were sufficient to outline regions of emission around the galactic center and anticenter, and also to show other maxima in Cassiopeia and Cygnus. As larger antennas with better resolution were built, more detailed charts were prepared of selected regions. Noteworthy are the map of the Cygnus region by R. Hanbury Brown and C. Hazard, and that of the area near the galactic center, by R. X. McGee, O. B. Slee, and G. J. Stanley. Other radio surveys have covered more extensive sky regions, but most of the antennas used had wide beams and revealed only the most general features of the background emission.

When the Ohio State University 96-helix antenna (see front cover) was completed late in 1953, a sky-mapping program was begun which has continued for over three years, supported by grants from the National Science Foundation and the fund for basic research of the university. The antenna is 160 feet long and 22 feet wide; working at a wave length of 1.2 meters, it has a beam-width of about one degree in right ascension and eight degrees in declination. This beam is narrow enough to reveal many details of the background radiation, and to resolve many discrete sources. As the work at Ohio State progressed, charts of parts of the sky were published, for example in *Sky and Telescope* for November, 1954, and July, 1955. These have now been combined and extended to form the new map shown here, which covers about 75 per cent of the sky—practically all of the heavens accessible from Columbus. In addition, the new map is more accurate than the older ones, because it has been corrected for distortion due to antenna side lobes.




**A radio profile of the deflections produced by the transit of the Crab nebula (Taurus A) and the nebulosity known as IC 443.**

For these mapping observations the antenna beam was set at a fixed declination. As the earth rotated, a narrow zone of the sky was swept out by the beam, and the power received by the antenna was recorded as a function of the time (or right ascension) by a pen on a moving paper tape. Each zone was reobserved on several days, and then the antenna was turned a few degrees to a new declination.

The sample profile reproduced here was obtained on December 21, 1955, at a declination of $+22°$. The general background radiation from the Milky Way produced a gradual rise; superimposed on this is a large deflection due to the transit of the intense radio source Taurus A (the Crab nebula), and a smaller peak probably due to the nebulosity IC 443. The vertical lines, extending downward from the profile at 10-minute intervals, are time marks impressed automatically from WWV time signals.

In compiling the map, the peaks on the profiles due to discrete radio sources were removed. Thus the contour lines of equal

radio brightness show only the general background radiation; the positions of the more intense discrete sources are represented by small circles.

The numbers on the contour lines indicate the "brightness" of the radio emission on a power scale above a reference level. It is often convenient to specify this brightness in terms of an equivalent temperature. On this basis, the contours show the radio brightness temperature above the coldest part of the sky (near the north galactic pole) at intervals of six degrees. The equivalent temperature at the galactic pole is about 80° Kelvin. Thus the equivalent temperature on the contour labeled "5" is 110° K, or $5 \times 6° + 80°$.

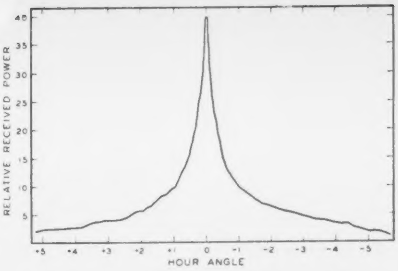
The dashed line indicates the galactic equator, and is marked in degrees of galactic longitude. Along the equator, the radio brightness increases toward the galactic center and shows a general decrease toward the anticenter. However, the minimum or col occurs at about longitude 193° instead of at 148°, the direction of the galactic anticenter. Another interesting feature of the map is that the ridge line of the background radiation tends to lie a little south of the galactic plane at most longitudes.

An outstanding discrete source is labeled "galactic nucleus" on the map. There is clearly a very intense localized source at the same place where the background radiation is strongest. Often referred to as Sagittarius A or as IAU 17S2A, its right ascension is $17^h\ 42^m\ 48^s$, declination $-28°\ 50'$, very close to the accepted direction of the galactic center. This region is obscured from optical observation by dense clouds of interstellar dust. But radio waves can readily penetrate these clouds, and the radio source may in fact be the galactic nucleus itself. When separated from the background radiation, the source has a flux density of $25 \times 10^{-24}$ janskys (1 jansky = 1 watt per square meter per cycle per second).

Recent studies by E. F. McClain and by R. D. Davies and D. R. W. Williams, using observations of the 21-cm. line of hydrogen, suggest that Sagittarius A may be identified with a dense H-II region lying in the direction of the galactic center, but closer to us.

An analysis of our high-resolution survey shows that the galactic radio radiation may consist of three parts: a thin belt about three degrees wide, lying nearly in the galactic plane and concentrated toward the galactic center; a much thicker zone of emission, about 15 degrees wide in galactic latitude; and, thirdly, an approximately spherical distribution. The first component is of predominantly thermal origin, while the other two are not.

Many discrete radio sources have been recognized during our survey by the sharp rises in intensity they produce on the recorded profiles. For a point source, the signature on the record is a direct measure of the antenna pattern, but with an




**A radio profile of the deflections produced by the galactic nucleus region, showing a very intense peak situated on a broad elevation of the general background radiation.**

extended source a broadened pattern is observed. On the map solid dots indicate localized sources and open circles denote extended sources. Only intense sources that can be detected by a single observation have been plotted. The magnitude scale has been arbitrarily chosen so that "1st magnitude" corresponds to a flux density of $10^{-22}$ janskys.

At our wave length of 1.2 meters, the most intense radio source in the sky is Cassiopeia A, at right ascension $23^h\ 21^m.2$, declination $+58°.5$. Next strongest is Cygnus A, at $19^h\ 57^m.7$, $+40°.5$, which has been identified with two colliding galaxies. Optically, Cygnus A is of the 18th magnitude. The most intense source in the winter sky is Taurus A, at $5^h\ 31^m.5$, $+22°.0$.

Radio sources are very difficult to detect if they are superimposed on a steep rise of the general background. Therefore, radio sources along the galactic equator, and especially near the galactic center, tend to be masked by background radiation.

In the winter sky the background is weak, and the masking may be negligible. It is in this region, therefore, that we have made a special study of the distribution of the sources. There is a very marked concentration of intense sources in the galactic plane. Another striking feature is that almost half of the sources have diameters of one degree or more. Many of these sources are known to be associated with unusual optical objects in our galaxy—the Crab nebula, IC 443, the Auriga nebulosity, the Network nebula, H-II regions, and peculiar filamentary nebulosities like those forming Cassiopeia A. Many unidentified intense radio sources near the galactic plane may be similar objects. There are also four radio complexes in Cygnus, Orion, and Vela, in some areas that are rich in diffuse nebulosities, early-type stars, and hydrogen-alpha emission regions.

The actual mechanism that produces the radio emission from our galaxy is still not understood. There have been proposals that it is caused by synchrotron radiation, or by interstellar gas radiation, but complete answers to these questions must await the use of larger and better radio telescopes.

## *VOLUNTEERS NEEDED FOR AURORAL OBSERVATIONS*

*(Continued from page 159)*

all synoptic map of a display of the northern lights.

The co-operation of volunteers in two organized visual projects is invited:

1. *Graphic Reporting Program.* Auroras are recorded in diagrammatic form on special data sheets. As the observer's experience increases, he can report more detail and measurements on these same sheets. Filters and simple angle-measuring devices can be supplied to observers.

2. *Alidade Program.* Measurements of the positions of auroral forms will be made with precision alidades. When one of these simple instruments is used to measure the meridian altitude of an auroral form, the observer has only to mark the angle directly on a card that is inserted in the alidade. This more detailed work will be carried out by organized groups able to make observations each 15 minutes on the dates specified as "special world intervals."

The visual auroral observation program in the United States and Canada is being operated jointly by Dr. C. W. Gartlein, Cornell University, and Dr. Peter M. Millman, National Research Council of Canada. Amateur astronomers in the United States who are willing to participate in this work should communicate immediately with Dr. C. W. Gartlein, IGY Auroral Data Center, Rockefeller Hall, Ithaca, N. Y., and observers living in Canada should communicate with Dr. Peter M. Millman, IGY Auroral Center, National Research Council, Ottawa, Canada.

## *SHADOWS CAST BY THE LIGHT OF VENUS*

When the planet Venus shines in a dark sky, it can cast shadows, but these are difficult to observe because of the background illumination of the sky, which floods the shadows with light. In the *Journal* of the British Astronomical Association, W. H. Steavenson, Cambridge, England, describes simple expedients to render the Venus shadows easily visible.

The observer uses a darkened room in which there is a single small window or opening through which only Venus and a few degrees of the surrounding sky can be seen. Then the light of Venus causes the shadow of the window frame to stand out vividly on the opposite wall. Since the planet is substantially a point source of light, the shadows are very sharp, not having the penumbral effects of shadows from extended sources such as the sun and moon.

An observatory dome can be used for seeing Venus' shadows, especially if the slit is of the roll-over type that can be closed down to form a small aperture.

# Galaxies and Their Interactions

Otto Struve

*Leuschner Observatory*
*University of California*

**This 200-inch photograph reveals a swarm of galaxies, mostly ellipticals, belonging to the great cluster in Corona Borealis. Unless otherwise indicated, the photographs with this article are from Mount Wilson and Palomar Observatories, many by courtesy of Fritz Zwicky.**

IN DECEMBER, 1954, the Statistical Laboratory of the University of California held an astronomical symposium, whose papers have now appeared in book form, constituting an important addition to astronomical literature.* On several previous occasions we have discussed the properties of the Hertzsprung-Russell diagram, which was one subject of the symposium. Therefore, we shall concentrate our present attention on the symposium's second topic, "Spatial Distribution of Galaxies."

There were three papers on this subject: G. C. McVittie, "Galaxies, Statistics and Relativity"; J. Neyman, E. L. Scott, and C. D. Shane, "Statistics of Images of Galaxies with Particular Reference to Clustering"; and F. Zwicky, "Statistics of Clusters of Galaxies."

Following the lead of pioneer investigators including Max Wolf, Harlow Shapley, and Walter Baade, observers and theoreticians today agree that the distribution of the galaxies is nonuniform; many galaxies, if not all of them, occur in more-or-less compact groups or clusters. This tendency is well illustrated by contour maps published recently by Shane and C. A. Wirtanen. The contours indicate equal numbers of galaxies per square degree, on the basis of counts made on plates taken with the 20-inch Carnegie astrograph of the Lick Observatory (*Sky and Telescope*, August, 1954, page 335).

Clustering of galaxies is much more widespread than casual inspection of the sky would indicate. Compare, for example, the accompanying twin charts, one plotted by Shane to show the galaxies on a Lick Observatory photograph, the other constructed synthetically by Neyman and Scott. The latter diagram is an artificial one, made under the assumption that all galaxies belong to clusters which, as seen

**Galaxy distribution in parts of Serpens, Bootes, and Virgo, is shown in this portion of a contour map from Lick Observatory. Contour-line labels give the number per square degree of galaxies at least as bright as magnitude 18.4. The cloud of galaxies in the upper left contains over 1,200 counted members in an area of 20 square degrees; an even richer cloud near the lower edge, with about 2,800 galaxies counted, may be made of overlapping clusters, as it has at least six centers of condensation. Both clouds are about 120 million light-years from us, on the revised distance scale; they had been studied earlier by H. Shapley.**

**Proceedings* of the Third Berkeley Symposium on Mathematical Statistics and Probability, Vol. III: Contributions to Astronomy and Physics, edited by Jerzy Neyman, University of California Press, Berkeley and Los Angeles, 1956, 252 pages, $6.25.

projected on the sky, overlap to give the impression of an irregular field of individual galaxies.

Nevertheless, since some clusters may contain only two or three galaxies and others several thousands, it is still possible to speak of the "general field of galaxies" as distinguishable from the large and relatively dense clusters.

Zwicky last year summarized our knowledge of clusters of galaxies:

1. Clusters and clouds of galaxies are the rule, rather than the exception.

2. The clusters tend to fill all space. Many are spherically symmetrical. The large spherical clusters resemble one another in structure.

3. A rich cluster may contain as many as 10,000 galaxies that are at least 1/600 as bright as its brightest member.

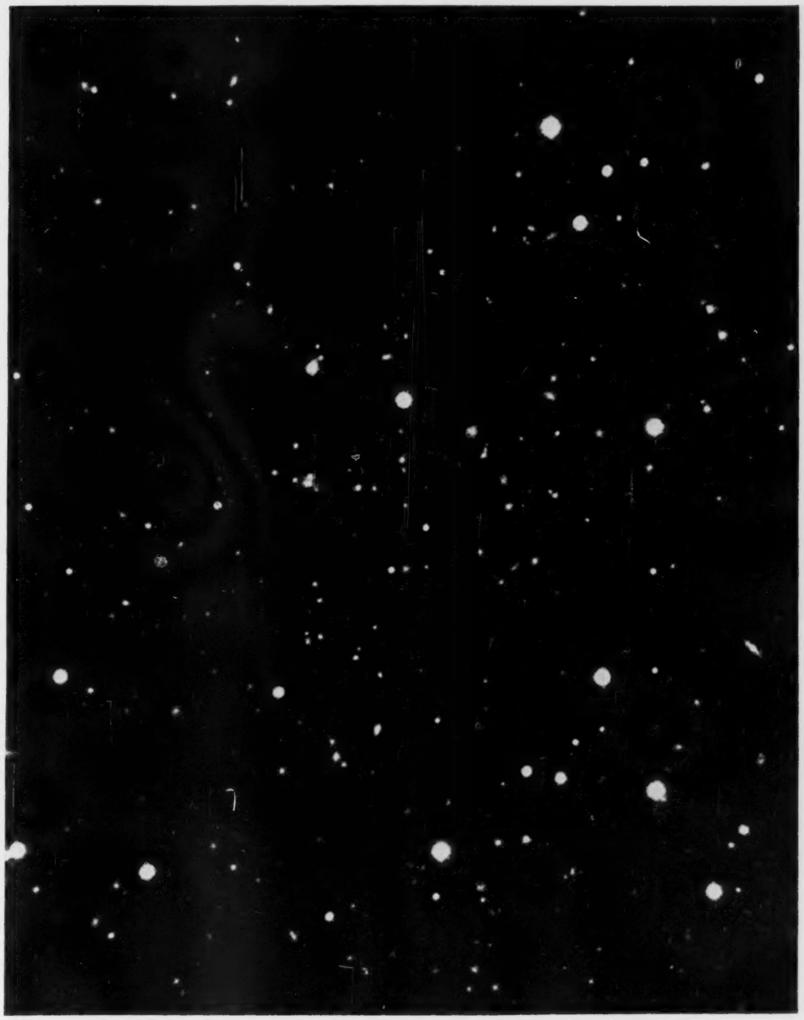
4. The space density of the galaxies in a cluster decreases from the center outward—imitating a famous case of the distribution of density derived long ago, by R. Emden, for isothermal gas spheres.

5. Very bright elliptical galaxies are more strongly concentrated toward the center of a cluster than are the spirals and the irregular systems.

6. The velocity dispersion within the large clusters is of the order of 2,000 kilometers per second.

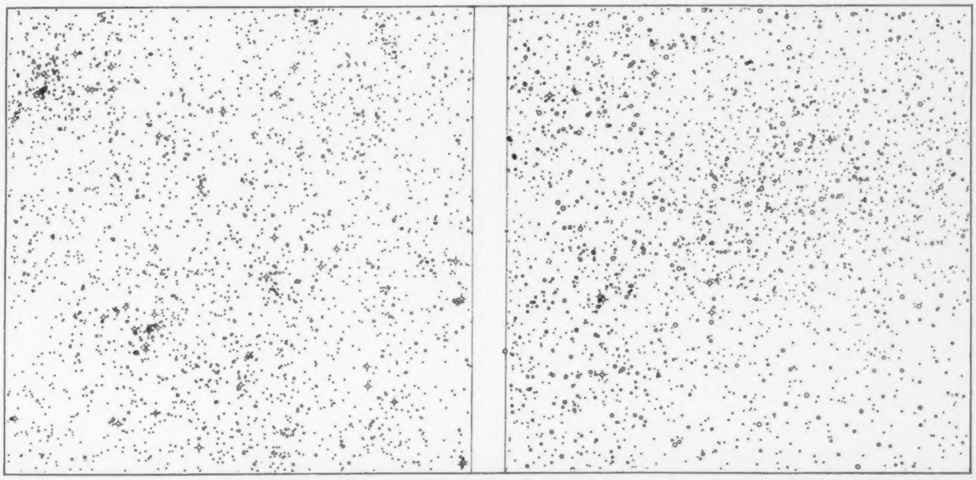
7. There seems to be some diffuse luminous and dark absorbing matter inside the clusters of galaxies. The luminous matter probably consists of stars—single or in groups—that may have been torn away from galaxies during collisions. The dark matter may consist of gas and dust.

8. Very faint galaxies in a cluster may be considerably more numerous than had been previously estimated. Long ago, Zwicky pointed out that the motions of the galaxies inside a cluster are faster than can be reconciled with the gravitational attraction of all the visible members. He has insisted that the *luminosity function* of the galaxies (numbers in one-magnitude intervals of intrinsic brightness) keeps on increasing for the fainter absolute magnitudes, instead of dropping off quite rapidly for galaxies that are five or six magnitudes fainter than the brightest members. Astronomers do not yet agree on the shape of the luminosity curve.



**On photographs made in 1934, with the 100-inch Mount Wilson reflector, this very distant cluster of galaxies in Hydra was discovered. The magnitudes of its brightest members are about 18.5. In the field above, taken with the 200-inch Hale telescope at Palomar Observatory, more than 200 of the galaxies in the Hydra cluster are recorded, though hundreds of millions of light-years away.**

Two of the most exciting problems are



**The left-hand chart indicates galaxies counted on a photograph taken in the Lick Observatory 20-inch survey. In the study of the tendency of galaxies to clump together, such actual charts have been compared with synthetic plots, as at the right. In the synthetic map, the points have been determined by a chance mechanism corresponding to a statistical model of cluster constitution and distribution. University of California diagrams.**

**In a 30-minute exposure on Eastman 103a-O emulsion, the 200-inch telescope recorded the galaxies in the cluster in Hercules shown here. It is located at right ascension 16$^h$ 3$^m$, declination +17°.9. The scale mark in the lower left indicates one minute of arc.**

the existence of close physical pairs of galaxies and the results of galaxy collisions. Let us, therefore, estimate the expectancy of a collision between two galaxies. In the observable part of the universe there are about three galaxies per cubic megaparsec (one megaparsec is a million parsecs). One galaxy is contained within a volume of $\frac{1}{3} \times 10^{18}$ cubic parsecs; the cube root of this number is the average distance between two neighboring systems—which thus turns out to be $7 \times 10^6$ parsecs or $2 \times 10^{19}$ kilometers.

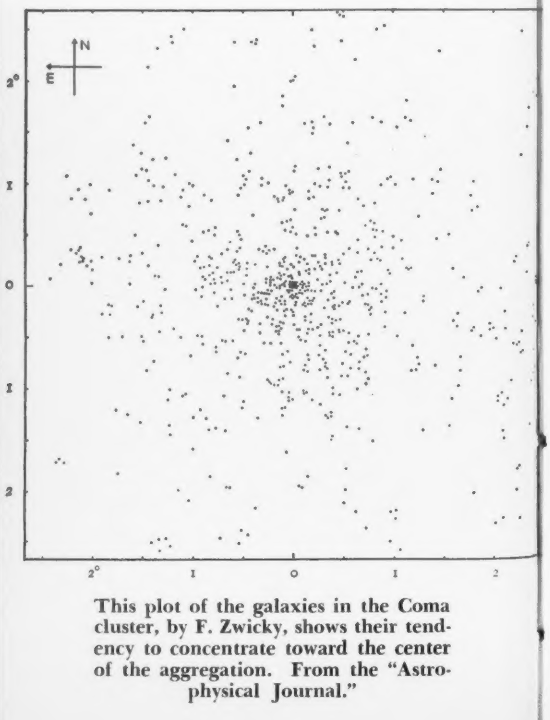
The average random radial velocity of a typical galaxy in the general field, and not in a dense cluster, is about 1,000 kilometers per second. Consider any one galaxy that is traveling at this speed with respect to its neighbors. For it to traverse the distance that separates it from its nearest neighbor would require $2 \times 10^{19}/10^3 = 2 \times 10^{16}$ seconds, or roughly one billion years.

But the motion of this particular galaxy may not be directly toward its neighbor. If the latter were the size of the Andromeda nebula, it would subtend in the sky a solid angle of about four square degrees. Let us therefore suppose that four square degrees represents a fair average. As seen from the moving galaxy, the other will cover only $10^{-4}$ (1/10,000) of the sky, since the entire surface of the sphere contains 41,253 square degrees.

Thus, each galaxy might expect a collision on an average of once in $10^9 \times 10^4 = 10^{13}$ years—far longer than the ages of the galaxies themselves. For our Milky Way system, or for any other specific galaxy in the general field, the event is much too unlikely to be of significance. Yet the number of galaxies in the general field is very large; throughout the observable part of the universe about one in every 10,000 might be expected to have collided with another galaxy during the past billion years!

In a dense cluster of galaxies, for example the one in Coma Berenices, the probability of collisions is much greater. In the central part of this cluster, the average distance between galaxies is only $2 \times 10^{18}$ kilometers, about a tenth as great as in the general field. Moreover, the ran-

**In this group of galaxies, known as Stephan's quintet, four spirals and one elliptical system are associated with each other.**




**This plot of the galaxies in the Coma cluster, by F. Zwicky, shows their tendency to concentrate toward the center of the aggregation. From the "Astrophysical Journal."**

dom velocities of the cluster members are larger than for field galaxies, about 2,000 kilometers per second. Near the center of the Coma cluster, $2 \times 10^{18}/2,000$ or $10^{15}$ seconds are required for any single galaxy to traverse the distance separating it from its nearest neighbor. This is only some 30 million years.

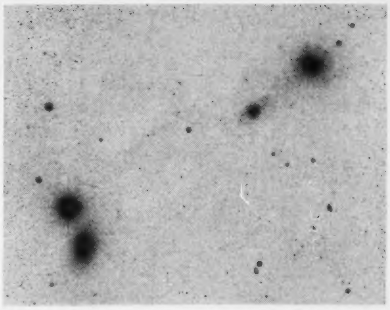
Furthermore, if the average distance between galaxies in the cluster is 1/10 that in the general field, the angular area of the "target" galaxy will be 100 times as great; it will cover $10^{-2}$ of the sky instead of $10^{-4}$, as seen from the moving galaxy.

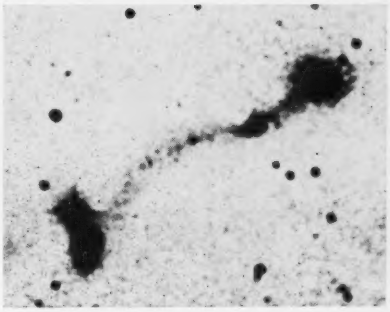
Thus, each galaxy in the cluster might be expected to collide with another once in $3 \times 10^7/10^{-2}$ or $3 \times 10^9$ years. This estimate agrees well with a more elaborate computation by L. Spitzer, Jr., and Baade, who concluded that an average galaxy in a cluster has probably experienced one or more collisions with another galaxy during the past three billion years.

For comparison, let us consider the probability of collision between two *stars* in the vicinity of the sun. The motion of the sun (or of a typical star in our spiral arm of the Milky Way system) is about 20 kilometers per second. Our nearest neighbor, the double star Alpha Centauri, is $4 \times 10^{13}$ kilometers away; it would take the sun 70,000 years to move such a distance. Moreover, the disk of one component of Alpha Centauri covers only about $2 \times 10^{-16}$ of the entire area of the sky.

On this basis, an individual star could collide with another once in about $70,000/2 \times 10^{-16}$ or roughly $10^{20}$ years. The probability of any one out of the billions of stars in the Milky Way ever having collided head on with another during the entire five-billion-year lifetime of the galaxy is extremely small. Even near misses are unlikely to have occurred.

Although collisions between stars are so improbable, collisions between galaxies are frequent occurrences, and the consequences of these encounters are actually observed. R. Minkowski has shown that several pairs of galaxies are in collision at the present time. The stars of the colliding systems are comparatively little disturbed, but their gases—mixing with each other at relative velocities of thousands of kilometers per second—produce enormous amounts of turbulence accompanied by the intense emission of radio waves. The most spectacular radio sources in the universe are precisely such colliding galaxies. (Two sources of this type, Cygnus A and NGC 1275, are shown on the Ohio State University radio map of the sky on page 160.)



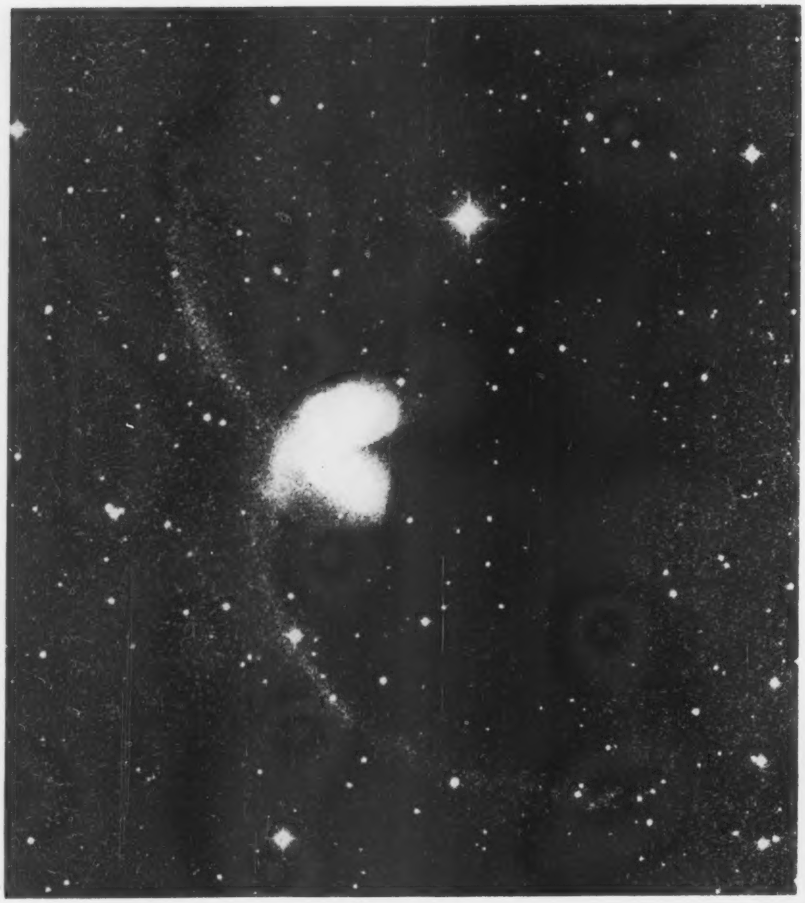


**Filaments of luminous material between galaxies are illustrated by these photographs. At the left, a 30-minute exposure with the 200-inch telescope shows tidal and countertidal extensions. The negative reproductions at the right reveal a scimitar-shaped bridge connecting the galaxies IC 3481 and 3483. The upper picture is by the 200-inch telescope, the lower by the 48-inch Schmidt camera of Palomar Observatory.**

The problems of double and multiple galaxies have recently been discussed by Zwicky in a remarkable summarizing article in *Ergebnisse der exakten Naturwissenschaften* (*29*, 344-385, 1956). He calls attention to the important contributions of earlier observers, H. D. Curtis, K. Lundmark, E. P. Hubble, and especially E. Holmberg; and he gives many photographs of extraordinary tidal disturbances in multiple galaxies.

There is much reason for believing with Holmberg that the formation of true double galaxies revolving around one another may be the result of mutual captures during close encounters. It is more difficult to explain the frequent occurrence of long luminous intergalactic "bridges" be-

**The 60-inch reflector at Mount Wilson Observatory recorded this double galaxy in Bootes, requiring an exposure of six hours on May 30-June 1, 1916. The two spirals are NGC 5857 and 5859 (right).**



**Long tidal filaments characterize this pair of colliding galaxies, NGC 4038-9, which is a weak source of radio energy. The photograph was made with the 48-inch Schmidt camera.**

**Until recently this object, NGC 750-1, was thought to be a simple "dumbbell" type of galaxy, without arms or extensions. But a prolongation to the north-northwest is revealed by this 200-inch photograph, on a blue-sensitive emulsion.**

tween rather widely separated systems. Zwicky remarks that several thousand formations of this kind can be seen in photographs taken with the 48-inch Schmidt telescope on Palomar Mountain.

He regards these bridges as the debris, produced during the encounter of two galaxies, which escapes into intergalactic space, and he suggests that the galaxies may actually be viscous enough to produce a long taffylike band between them. As far as has been ascertained, these luminous bridges show no emission lines in their spectra; they are like distorted spiral arms, consisting mostly of stars. The possible origin of such a formation during a galaxy collision is illustrated in Zwicky's diagram reproduced here.

A striking case of a luminous bridge is that connecting the 15th-magnitude spiral galaxies IC 3481 and IC 3483, which are about four minutes of arc apart on the sky. A faint, curved band that links them is distinctly shown by Zwicky's 48-inch Schmidt photographs. On 200-inch plates, however, the intergalactic band is less evident, because the greater speed of the Schmidt makes it more effective in recording very faint extended surfaces.

Lying on this bridge is a third, uncatalogued galaxy of magnitude 16, so that the system is actually triple; it is readily seen as such in the photographs on page 165. The red shifts of all three galaxies have been measured by M. L. Humason with the 200-inch reflector. Both IC 3481 and the anonymous galaxy have apparent velocities of recession of about 7,300 kilometers per second. Most surprisingly, IC 3483 is receding at only 100 kilometers per second. Zwicky maintains that there is no doubt the three galaxies form a triple system and that all are nearly at the same distance from us; but the enormous relative velocities within this multiple system are difficult to explain.

The ultimate fate of the bridges between galaxies is not known. But it is reasonable to suppose that they gradually disperse into space, forming a fairly uniform medium of very old stars and intergalactic gas and dust. This makes it appear that the structure of the universe is undergoing a gradual degradation; the complicated spirals and ellipticals slowly dissolve into a uniform intergalactic medium. We do not see the reverse process, the formation of individual galaxies.


**The possible formation of an intergalactic bridge is here sketched by F. Zwicky. The globular galaxy A moves with velocity V past an elliptical galaxy B which is rotating in a clockwise direction. Because of this initial rotation of B, the tidal bridge formed in parts b) and c) must ultimately be ruptured and the break shown in d) will occur. The globular galaxy now appears as a spiral. Part d) represents the essential features discernible on a 200-inch photograph of a double system near the north celestial pole. From Reprint No. 206, of the Mount Wilson and Palomar Observatories.**

# ASTRONOMICAL SCRAPBOOK

## Two Unusual Occultations Observed in 1797 and 1798

ONE of the most striking of telescopic views is the occultation of a 1st-magnitude star by the crescent moon in the evening sky. In the eyepiece field you see the star close to the edge of the moon's dark side, which is faintly visible by earthshine. From minute to minute the separation between moon's limb and star steadily narrows, and you gain the clear impression of our satellite as a great globe in rapid motion through space. Finally, as the dim gray lunar edge reaches the star, the brilliant point of light is snuffed out with startling abruptness.

Perhaps an hour later, if you are watching just the right place on the illuminated limb of the moon, you will see the sudden appearance of a tiny, bright mountain that detaches itself, and becomes recognizable as the same 1st-magnitude star, now once more free of the moon.

Occasionally curious variations are witnessed in this pattern. Two uncommon occultations have been reported in detail by the famous German amateur, J. F. Schröter, whose observatory at Lilienthal, near Bremen, was a very active center for lunar and planetary study near the beginning of the 19th century. (There was some account of his life in this column for February, 1955.)

Schröter was interested in the possibility that occultation observations might indicate a lunar atmosphere. On the morning of July 31, 1798, he prepared to watch an occultation of the planet Mars, then only six weeks before opposition. His instrument was a reflector of 13 feet focal length, bearing a power of 136x. Alongside Schröter was his son, who observed with a smaller reflector made by William Herschel; Schröter's assistant, K. L. Harding, employed a Dollond achromatic refractor.

The clouds that had prevailed began to clear in time for the trio to note the first contact of Mars and the moon. The occultation was a grazing one, so this contact was near the moon's south pole. Three minutes later, Schröter estimated that the planet's disk was half covered. But then for 15 minutes he watched the partially occulted planet run along the moon's mountainous southern rim, with a third of the Martian diameter always remaining visible. It was an unusually beautiful sight, the Lilienthal astronomer recorded; there was a fine color contrast between the yellow of the moon, the orange-red of the Martian disk, and the brilliant white of the planet's south polar cap. Then Mars became more and more uncovered, and finally broke loose from the moon's limb, in the neighborhood of the Leibnitz Mountains. There had been no appearances attributable to a lunar atmosphere.

Eyewitness reports of partial occultations of planets by the moon are very rare, but the phenomenon itself is common. It should be visible from somewhere on the earth's surface every time a planet is occulted. The observer must, however, be inside a very narrow zone at the extreme north or south of the geographical area from which the occultation is visible. Perhaps some Latin-American watcher of the occultation of Mars on the afternoon of February 6th, this year, will see this effect.

Another peculiar occultation Schröter witnessed was on the evening of September 26, 1797; it seems to have been unique in his experience. With the same 13-foot reflector he watched the disappearance of a moderately bright star in Ophiuchus behind the dark edge of the 6-day-old moon. On its arrival at the limb, the star lost brightness, but remained visible as a fine point of light for seven or eight seconds more before vanishing. To Schröter it seemed that the star was fading steadily during this interval.

This unexpected behavior puzzled Schröter greatly. Did the "star" have a disk? If so, its diameter must have been 3½ or 4 seconds of arc, corresponding to the moon's travel during the interval. He dismissed the possibility that a star could have such a disk, and asked himself whether the object was an unknown planet. However, he could hardly have failed to recognize a planetary disk as large as that of Uranus while using a power of 136x, he tells us. (Neptune, by the way, was in another part of the sky on that date.)

Nor could the effect be due to dimming by a lunar atmosphere. Too much atmosphere would be required, contradicting his other studies. Moreover, occultations that he had previously witnessed did not show such a phenomenon. The only explanation, he concluded, was that the star must have passed obliquely behind a very high, nearly vertical mountain wall. This appeared the more reasonable to him, as the point of disappearance was east of the crater Grimaldi (dimly visible by earthshine), and therefore in the rugged D'Alembert Mountains at the moon's limb.

Today the phenomenon is less strange than in Schröter's day, when occultations were not predicted and therefore seldom observed. His description strongly suggests that the star was double, and that after the bright primary was covered a faint companion star remained visible for several seconds more.

To test this interpretation, we must first identify the star. The final disappearance was observed at 6:37:02 p.m., Greenwich mean time. From the *Nautical Almanac* for 1797 we can obtain the approximate position of the moon for the time in question. As seen from Lilienthal where Schröter observed, the apparent right ascension and declination of the moon were $17^h\ 22^m.1$, $-24°\ 32'$. Since the star disappeared near the east point of the moon's limb, its co-ordinates would be about $17^h\ 23^m.2$, $-24°\ 32'$, for 1797.0.

From this we can identify the star as probably Cordoba A 12082, whose position for 1797 is about three minutes of arc from that we have just found. The discrepancy seems no larger than would result from the crudeness of the old lunar ephemeris and from other uncertainties. The visual magnitude of 7.8 found by the Cordoba observers fits with Schröter's description "moderately bright." The 1950 position of Cordoba A 12082 is $17^h\ 32^m.5$, $-24°\ 36'$.

However, Cordoba A 12082 is not a known double star, to my knowledge. It would be worth while for some observer to examine it for a hitherto unrecognized companion. To fit Schröter's account, the companion would be about magnitude 10, at a distance of roughly four seconds of arc near position angle 90°.

This description applies to the pair in 1797. What about 1957? If the system is a visual binary, the relative position of the two components may have changed very little. On the other hand, the pair may be merely an optical double. Cordoba A 12082 has a large proper motion toward the northeast, amounting to 0.12 second of arc per year. If the fainter star were an independent, purely optical companion, it would have been left far behind, and we would expect to find it now about 18 seconds of arc from the 7.8-magnitude star, in position angle 200°.

Dr. W. H. van den Bos, Union Observatory, has suggested another explanation of Schröter's observation—a faint asteroid might have passed close enough to the star on September 26, 1797, to have formed a "double star."

JOSEPH ASHBROOK

Schröter's account of these observations is in his *Selenotopographische Fragmente*, Part 2, Göttingen, 1802; I am indebted to Mr. Ole Groos for the opportunity to consult this book in the library of the Geophysics Research Directorate, Air Force Cambridge Research Center. Other details about the occultation of Mars are in Schröter's *Areographische Fragmente*, Leiden, 1881.

# A Hollow Meteor Train

Gerald S. Hawkins, *Harvard College Observatory*

IN ITS PASSAGE across the sky a bright meteor leaves behind a glowing column of light which is called the meteor train. A Perseid meteor as bright as Venus will normally leave a train that persists for five seconds; an observer who watches the Perseid meteor shower throughout the nights of August 10-12 will probably see one or two trains of this duration.

Trains lasting for more than five minutes are exceedingly rare, and for the average observer occur about once or twice in a lifetime. Thus, not more than a hundred or so long-enduring trains have been recorded since the beginning of meteor astronomy. Besides being rare, trains are difficult to observe because of their faintness. Furthermore, winds in the upper atmosphere rapidly distort and displace the train, so details of its form are best studied visually, as they become smeared out in a photograph exposed for more than a few seconds.

Observations of the structure and expansion of meteor trains are required in connection with two problems. First, the mechanism of production of light in such trains is not well understood. The writer and A. F. Cook have already shown that it is not due to the recombination of positive ions with electrons. As noted in *Sky and Telescope* for June, 1956, page 359, one second after a very bright Perseid occurs, a centimeter-long section of its train emits about 400 ergs of visible energy per second, but only a little more than one erg of this is due to recombination. To develop the subject further, we need to know the distribution of light across a typical meteor train. Second, after the meteor train forms, it immediately begins to expand, and the rate of expansion gives a measure of the rate of diffusion in the atmosphere at the meteor's height, which for bright Perseids is about 95 kilometers or more than 50 miles.

The writer was very fortunate, therefore, to be observing at the Harvard meteor station at Sacramento Peak Observatory in New Mexico during the Perseid shower last year. At 1:38:42 Mountain standard time on August 11th a Perseid meteor of maximum apparent visual magnitude $-3$ left a persistent train lasting for 5 minutes 40 seconds!

The Harvard meteor project at Sacramento Peak is equipped with two Baker super-Schmidt cameras that can photograph meteors as faint as visual magnitude $+4$. The film in one camera is exposed for 12 minutes, with a rotating shutter in the focal plane so that any meteor appearing in the field of view during this period is recorded as a series of bright dashes. A visual observer watches the same sky area as the camera during the exposure to record the time of appearance, visual magnitude, and other details concerning each meteor that is photographed.

A second camera is used to photograph any train produced by meteors in the same field; instead of a rotating shutter there is a large blind across the front of the camera which is opened by a signal from the visual observer when a meteor train appears. Successive images of the train are recorded on the film by displacing the camera in steps of half a degree in declination.

The Perseid of August 11th flashed in a part of the sky outside the field of the cameras at the time, so no direct picture was taken. But in about two minutes, observers Gunther Schwartz and Fred Maxwell were able to turn the train-recording camera toward the train and to make four exposures before it faded, each shifted with reference to the preceding one by half a degree. The four images of Mars, much overexposed, blended to make the bright streak at the right. The three rectangular streaks at the top are sensitometer marks superimposed on the negative to aid in brightness measurements. In the center left the meteor train extends downward and bends abruptly to the left; this much

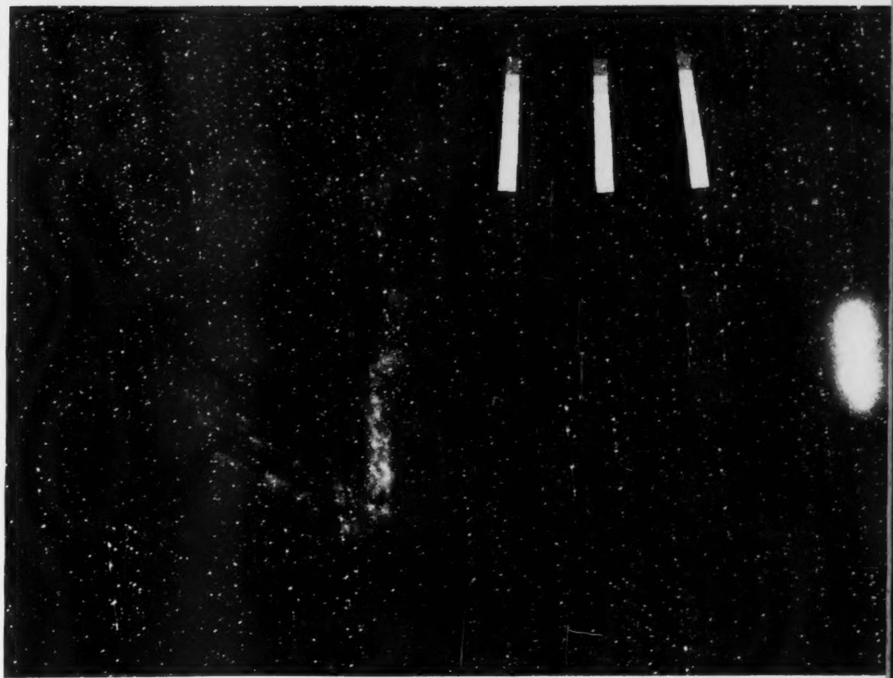
**The meteor train picture described here was taken by one of the extremely fast super-Schmidt meteor cameras in New Mexico. The present locations of these cameras are at Sacramento Peak Observatory and at Mayhill, about 22 miles away. Harvard Observatory photograph.**

distortion had occurred before the picture was started.

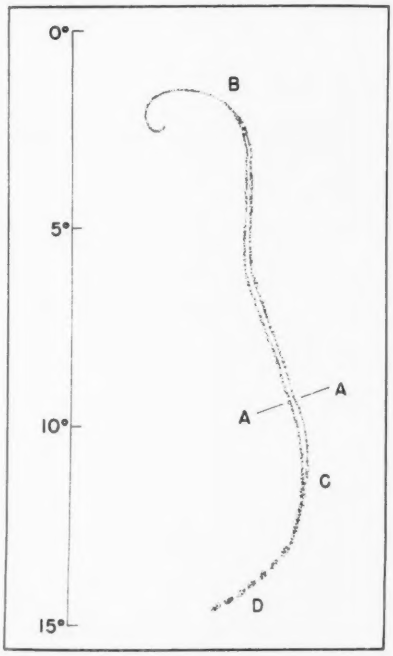
The blind was opened at 1:40:58 MST, and the camera was moved rapidly through half a degree in declination at 1:41:00, 1:41:09, and 1:41:15, the shutter being closed again at 1:41:26 MST. Some of the bright star images are therefore connected by streaks they made during each shift. The exposures were for 2, 9, 6, and 11.4 seconds, respectively, the first one too short to record the meteor train. Unfortunately, the train lay approximately in a north-south line, which caused the images in the main part of the train to overlap; they can be more distinctly seen in the part extending back to the left.

A few seconds after the meteor appeared, its train was about 14 degrees long and of a reddish-yellow color. No optical aid was used until 33 seconds later, when I began observations with a pair of 7 x 42 binoculars. The train had a remarkable appearance, being double along a portion of its length, but I do not know just when during the 33 seconds this double nature had developed. There was already noticeable distortion of the initial linear column, with its lower portion becoming bent and irregular.

During the next few minutes the train continued to expand, the bend in the lower portion became more pronounced, and the whole train showed a steady drift toward the southwest. The double nature of the train persisted until it was five minutes old, when it became a uniformly bright streak about half a degree across. Its brightness gradually decreased, the last part to fade away being the lower horizontal section. The details shown in the drawing are not visible in the photograph, because the train was blown about by upper-air winds during each time exposure.



Three overlapping images of the meteor's train are recorded in this photograph, the first being taken 2.3 minutes after the meteor flashed across the sky. The overexposed images of Mars overlap at the right, and three sensitometer marks are at the top. Photograph courtesy Geophysics Research Directorate, Air Force Cambridge Research Center.



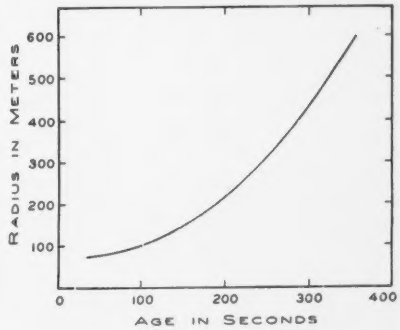

**The heights above the ground for points on the train were computed from measurements of the photograph, assuming part A-A to be 88 kilometers high. For B the height was 92.4 kilometers, for C 82.4, and for D about 76 kilometers.**

Some 50 years ago it was suggested by C. C. Trowbridge that a meteor train may be a hollow cylinder, and this seems to be the best explanation of the double nature of this Perseid train. When such a cylinder is small, its edges should appear brighter than the space between them, but as it expands this difference should become progressively less noticeable.

This fact makes it possible to compute the dimensions of the cylinder. The double structure of the train disappeared when it was about 300 seconds old, with a total diameter of 800 meters. If we assume that the hollow structure became invisible when the center was half a magnitude fainter than the edge, the external radius at 300 seconds was 400 meters and the internal radius 170 meters. We may therefore assume that at this stage turbulent eddies were operating with diameters equal to the thickness of the wall of the cylinder, 230 meters.

The evidence that a hollow cylinder developed appears to confirm the belief that the light from meteor trains is not produced by recombination of positive ions and electrons, for the rate of recombination is too small to remove the ions in the center of the cylinder in a period of only 30 seconds. In other words, were recombination the sole source of the light, the hollow nature of the train could not appear so quickly. It seems that the particles causing the emission of light in the center of the train are depleted by a factor of two or more in just a few seconds, and this process strongly resembles the reaction that would be produced by injecting a catalyst such as nitric oxide into the atmosphere.

The observations described here were made while doing work under Department of Defense Contract AF19 (122)-458, Subcontract No. 57.




**Rapid expansion of the train took place and continued during the entire time it was visible. At an age of five minutes (300 seconds), its diameter was about half a mile.**

# Satellite-Tracking Practice in a Planetarium

RICHARD H. EMMONS, *Goodyear Aircraft Corporation*

EXPERIMENTAL observations of an artificial satellite in a planetarium sky are part of the training program of our MOONWATCH team in North Canton, Ohio.

Our volunteer group of 24 observers from the Canton-Akron area was organized last June, around a nucleus of amateur astronomers, but the majority are engineers and technicians working with guided missiles for the Goodyear Aircraft Corporation.

This team holds frequent meetings at the North Canton Planetarium to consider a wide range of related topics, such as observing equipment, stellar magnitude, WWV time signals, and celestial co-ordinates, all intended to prepare us for the demanding task ahead. Whenever possible, these discussions have been illustrated by demonstrations of actual observing devices, and by training aids such as slides, illuminated models, and specially developed planetarium apparatus.

The planetarium, which was described on page 214 of *Sky and Telescope* for March, 1956, has a dome 14 feet in diameter, under which 36 persons can sit. The star projector, as well as auxiliary projectors for planets and other objects, were constructed by me. For the satellite work, we designed a simple device to project the image of a moving satellite on the dome, including such important characteristics as its change in angular velocity, increase in apparent brightness toward the zenith, and the like.

In planning a satellite simulator, the first step was to study the geometry of the apparent motion of the satellite. Formulas were derived expressing the angular speed and altitude above the horizon, as seen by an observer, in terms of the satellite's elevation above the earth's surface, its orbital speed, and the angle at the earth's center between the observer and the satellite. This analysis was simplified by the assumption that the observer was located in the plane of the satellite's orbit, a situation that will in reality occur infrequently.

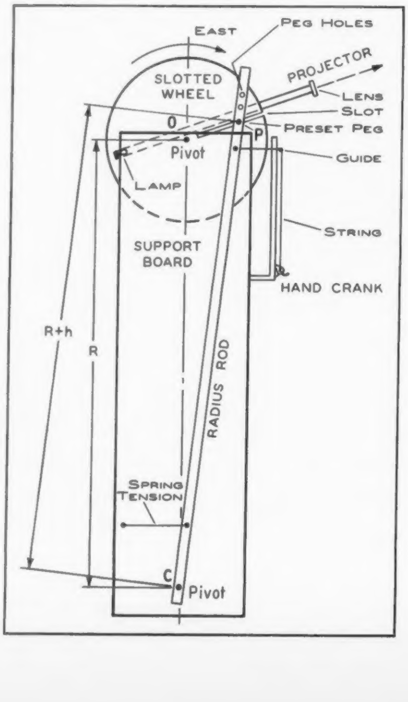
In the photograph, the planetarium star projector (white ball) is at the upper left, the control board and driving mechanism below it. The satellite projector lamp and optics are in the long tube pointing to the upper right and attached to a large slotted wheel, which is pivoted at the very top of the broad board. At the foot of this board is the pivot for the long radius rod that controls the motion of the wheel. This rod is operated by string controls from the reduction-gear unit attached to the right side of the board; the hand crank that turns these gears is not visible in the picture.

Refer to the diagram to understand the operation of the device: The pivot at $O$ represents the observer, while that at the foot of the board is $C$, the center of the earth. The pivot at $P$ between the radius rod and the wheel represents the satellite; as the radius rod contains several peg holes, the distance $CP$ can be adjusted to various orbital distances. The ratio $CP/CO$ should be the same as $(R + h)/R$, where $R$ is the radius of the earth and $h$ is the height of the satellite above the earth's surface.

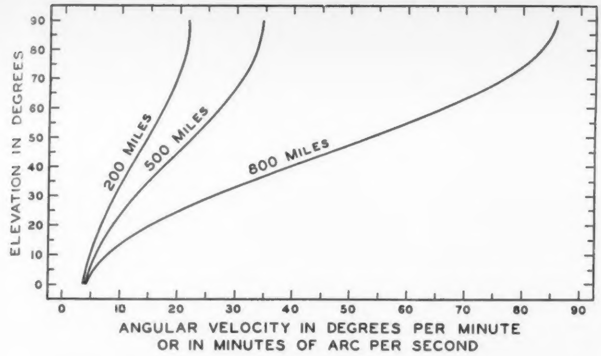
This device is easily constructed. The slotted wheel can be made from thin fiberboard, and the supporting board and radius rod from wood. At the North Canton Planetarium, we used 34 inches for the radius of the earth; thus, for a satellite 200 miles up, the corresponding length of the radius rod is $35\frac{3}{4}$ inches.

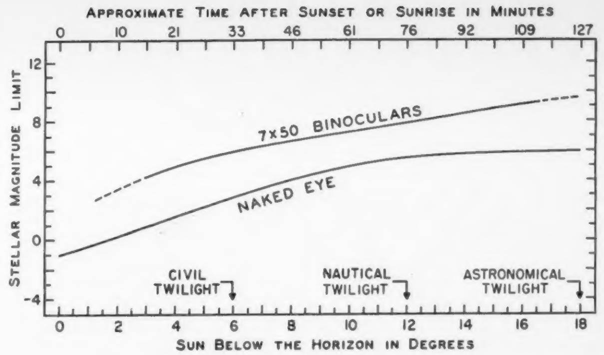
The brightness of the simulated satel-

**Left: The planetarium at North Canton, Ohio, was built by Mr. Emmons. Here is seen the recently added attachment for demonstrating an artificial satellite. The long tube at the upper right is an auxiliary projector that casts an image of the satellite upon the domed planetarium ceiling.**




**Right: The principle of the satellite simulator is shown in this diagram, which can be compared with the photograph. All illustrations with this article are by Mr. Emmons.**




**Left: How fast will an artificial satellite appear to travel across the sky? Mr. Emmons has plotted three curves, each for a different height above the earth's surface, to answer this question.**

**Right: How faint a sky object can be seen under specified twilight conditions? This limit has direct bearing on satellite observing, but depends on the observer and his sky conditions. These curves are based on sightings of stars in twilight by the North Canton observers on two dates last June.**

lite can be closely controlled by a rheostat for the projector; the brightness of the stars in the planetarium sky can be similarly set for any desired observing conditions. By means of a projector shield or a preset current switch, we are able to demonstrate the disappearance (eclipse) of the satellite that will occur as the satellite travels eastward across the twilight sky into the shadow of the earth.

With this simple device, a surprisingly realistic demonstration of the satellite's appearance is possible. Imagine yourself seated inside the dome, looking upward at the planetarium sky set for evening twilight in November (see October *Sky and Telescope* star chart). Soon you see a starlike point of light emerge from the western twilight arc—it is at the very threshold of vision, but as it ascends the western sky at increasing apparent velocity it also brightens and grows more conspicuous. Passing south of Hercules and touching Lyra, it crosses Cygnus to reach the zenith, attaining maximum speed and brightness. Descending eastward into a darker sky, the mock satellite passes north of the Great Square of Pegasus and, with slackening speed, crosses the Andromeda nebula, M31. It moves onward to midway between Cetus and the Pleiades, but there the point of light suddenly vanishes into the earth's shadow. The whole process has taken six minutes.

It is important to realize that the above demonstration does not necessarily give the proper appearance of an artificial satellite, which will probably be too faint to be followed without optical aid. But the planetarium observer can get a much better concept of the satellite's actual passage than from any other method of describing it to him. To get closer to reality, we have also used the satellite projector for a reproduction (on a very large scale) of what the observer may see through a MOONWATCH telescope. The entire planetarium dome was darkened except for a circular field of view containing stars. A narrow black tape on the dome bisected this field vertically, in imitation of the shadow of a meridian mast or of a reticle in the telescope itself. As the simulated satellite blinked out in passing the meridian mark, an observer called "time." His voice signal was tape recorded, superimposed on WWV time signals (see *Sky and Telescope,* October, 1956, page 542).

For such tests, conditions were varied widely. On some runs the twilight was too bright, the satellite was too dim, and no observation was possible. Observers did not know when or where to expect the satellite, as it could be made to cross the field either high or low. There was one significant incident when an observer called "time" while the operator was waiting to make a run! This brought about a discussion of the importance of verification of observations.

The mathematical analysis gave such information as the accompanying plot of angular velocity for a satellite at various heights above the earth's surface and at various angles above the horizon, again on the assumption that the observer is in the plane of the orbit.

Tests on magnitude limits during twilight for the naked eye and 7 x 50 binoculars were conducted at North Canton in June, 1956. These consisted of carefully timing the threshold evening appearances or morning disappearances of stars of known magnitude. On the graph, the depression of the sun below the horizon at each time is given, which should permit the curves to be applied to other seasons of the year for which the duration of twilight is not the same; also to other latitudes and elevations than ours in Ohio, where we are at latitude 41° north and 1,000 feet above sea level.

In all this work, which has given our observers a valuable foretaste of the problems of MOONWATCH observations, we have had the assistance and encouragement of the national advisory committee member for the Ohio area, Steadman Thompson, of Columbus. D. C. Romick, R. J. Couts, and the writer serve as a committee-in-charge for the local group project.

## *ATMOSPHERIC REFRACTION*

Navigators at sea and in the air depend on tables of refraction to correct their observations of altitudes of the sun, moon, and other celestial bodies. In recent years attempts have been made to check the tables for very low altitudes, where the effects of atmospheric refraction become very large. In the summer of 1955 the Greenland icecap expedition, known as JELLO, provided opportunities for repeated low-altitude measurements of the midnight sun under the uniform atmospheric conditions that prevail over the extremely cold snow surface of the Arctic subcontinent.

The expedition was conducted by the Snow, Ice, and Permafrost Research Establishment of the U. S. Army Corps of Engineers. George Wallerstein, now at the California Institute of Technology, reports the results in the September, 1956, issue of *Navigation.*

As the expedition members traveled from Thule east and then south to the French Central station, the sun was observed with a Wild T-2 theodolite twice each day, at noon and at midnight. The difference between the two latitudes so determined for each observing station could then be taken as the error in the refraction tables for the low-sun observation. In this way, 72 determinations of refraction were made between solar altitudes of 10° 16′ and 8′.

Wallerstein concludes that the navigator of a ship or aircraft may observe the sun as low as one degree above the horizon with errors of no more than a minute of arc from uncertainties in refraction. There is danger of considerably larger error, if high-flying aircraft observe the sun more than 90 degrees from the zenith and extend the refraction tables by extrapolation.

# A Pioneer in Canadian Astronomy

RUTH J. NORTHCOTT, *David Dunlap Observatory*

THE LIFE of Clarence Augustus Chant is very nearly the history of astronomy in Canada. Dr. Chant died on November 18, 1956, at his home, Observatory House, Richmond Hill, less than 10 miles from the place of his birth 92 years earlier. He was professor emeritus of astrophysics at the University of Toronto and director emeritus of the David Dunlap Observatory.

He was graduated from the mathematics and physics course of the university in 1890, and one year later was appointed to the faculty in the physics department. From then until his retirement in 1935 he taught at the university, except for a year's absence in 1901 for his Ph.D. degree at Harvard University.

Although there was some stirring of interest in astronomy as early as the middle of the 19th century, it was not until 1890 that astronomy gained a permanent foothold in Canada. In that year, the Astronomical and Physical Society of Canada was formally organized by a group of amateurs, and the first government observatory, a modest frame building, was erected in Ottawa.

In Toronto, Dr. Chant attended a few of the society's meetings, becoming a member in 1892. At the meetings he listened to reports of actual observations of objects in the sky. These discussions aroused in him an intense fascination for the science, and he dedicated the rest of his long life to promoting the study of astronomy. It was by his vision and effort that the University of Toronto established a department of astronomy; that the successor to the first society, the Royal Astronomical Society of Canada, branched out to form centers across Canada; and that a major observatory was established at Richmond Hill.

Little astronomy was taught at the university when Dr. Chant joined its staff. At his urging, a department of astrophysics was established in 1904, and a graduating course in astronomy was added to the curriculum. As head of the department, Dr. Chant trained most of the astronomers in Canada, and five of his students became directors of Canadian observatories.

While he was president of the Royal Astronomical Society of Canada from 1904 to 1907, the society opened centers in other parts of Canada and added members outside the country. He also reorganized the society's publications, including the monthly *Journal* and the annual *Observer's Handbook*. Dr. Chant was their first editor, and at the time of his death had been editor for exactly 50 years. These publications have added to

**C. A. Chant (1865-1956), an outstanding figure in the growth of present-day Canadian astronomy.**

the prestige and growth of Canadian astronomy.

The society has grown from a small group of members in Toronto at the beginning of the century to some 2,000 in 13 centers from Victoria in the west to Halifax in the east. About 500 members live outside Canada. Dr. Chant wrote in the jubilee number of the *Journal*, September, 1940, "The service rendered to Canada by our chain of organizations across the land cannot be calculated. They help to keep raised high the torch of pure learning in this world of turmoil and war and they minister directly to the education, culture and happiness of the people."

Anxious to emphasize the practical side of astronomy, Dr. Chant felt the need for a large telescope, and in 1912 began a persistent campaign to obtain such an instrument. After many disappointments, in the late 1920's the university was offered an observatory by Mrs. Jessie Donalda Dunlap to be built as a memorial to her husband. Mr. Dunlap, a member of the astronomical society, had come under the spell of Dr. Chant's lectures and had been interested in the observatory project. On May 31, 1935, as Dr. Chant reached the retirement age of 70, the David Dunlap Observatory with its 74-inch reflecting telescope was formally dedicated. However, his retirement was not idleness, for he revised his textbooks, edited the society's publications, and wrote his memoirs.

Dr. Chant was a fellow of the Royal Society of Canada, the Royal Astronomical Society of London, and a former vice-president of the American Astronomical Society. The Royal Astronomical Society of Canada in 1940 established the Chant medal in his honor; it is awarded for outstanding amateur contributions to astronomy.

Dr. Chant's amazing memory and active mind remained with him to the last. As recently as the September-October, 1956, issue of the *Journal*, he wrote an obituary on Walter S. Adams. His wise counsel will be missed by those who were fortunate to work near him.

## *MARTIAN GEOLOGY*

The interpretation of the surface of the planet Mars is essentially a geological problem, but this approach has been relatively neglected, according to D. B. McLaughlin in last October's *Scientific Monthly*. He believes that Mars and the earth have had very different histories, because of the extreme scarcity of water on Mars. Hence the most effective geologic processes in shaping the earth's surface are not necessarily the same as those most important on Mars. The table below, taken from the Michigan astronomer's paper, gives his appraisal of the factors that may have brought the surface of Mars to its present condition.

| *Agency or Process* | *Operative on Mars?* |
|---|---|
| Rain | No |
| Snow | Doubtful; surely very little |
| Frost | Yes, observed |
| Fluvial erosion and deposition | No |
| Wave erosion | No |
| Marine sedimentation | No |
| Talus formation; gravity sliding | Very minor, if present |
| Ice wedging | Very minor or absent |
| Glacial erosion and deposition | No |
| Chemical weathering | Yes; perhaps slow |
| Exfoliation | Yes; if solid rock is exposed |
| Wind transportation and deposition | Yes! |
| Action of living organisms | Quite surely minor, if present |
| Gravity faulting | Probable |
| Orogeny (folding and thrusting) | Unlikely |
| Volcanism | Possible; strong indirect evidence |
| Artificial operations | Almost certainly *no* |

Dr. McLaughlin's article explains in detail his hypothesis that the dark markings on Mars are drifts of wind-blown volcanic ash (see *Sky and Telescope*, September, 1954, page 372), and discusses some recent criticisms of this interpretation.

# By-Products of the Search for Natural Satellites of the Earth

Charles F. Capen, Jr., *New Mexico College of Agriculture and Mechanic Arts*

In December, 1953, a systematic photographic search for small *natural* satellites or moonlets of the earth was begun at Lowell Observatory in Flagstaff, Arizona. It was conducted by Clyde W. Tombaugh for the Office of Ordnance Research, Ordnance Corps, U. S. Army.

The first phase of the search came to a close in June, 1956, when certain survey zones of the sky accessible from the Lowell Observatory's latitude of 35° 12′.5 north had been covered. Mr. Tombaugh, who normally works as an astronomer at White Sands Proving Ground, is at present a research professor at New Mexico College of Agriculture and Mechanic Arts, from which he is directing a continuation of the search at an observing station in Ecuador.

As recently described by Mr. Tombaugh in *Jet Propulsion*,* the regions of space nearest the earth are virgin fields for such exploration. The angular velocity of a close satellite would be very great, so it could not be recorded on normal astronomical photographs. At the distance of the moon, an object of low reflectivity and less than 100 feet in diameter would be about 13th magnitude, probably detectable only by a fast camera driven at the proper angular rate. The accompanying chart (Fig. 1) shows stellar magnitude as a function of size and distance, assuming that a natural satellite would probably have a rough surface and, like the moon, would reflect only about seven per cent of the incident sunlight.


**Fig. 1. In this diagram, Clyde Tombaugh has assumed that a hypothetical satellite is seen at full phase (opposite the sun in the sky) and that it reflects seven per cent of the sunlight falling on it. A satellite in area "A" could be found by existing telescopes with standard drives; in "B" it should be detectable with the f/1.6 Schmidt and special drive used in the Ordnance Corps satellite search; in "C" a natural satellite would be even more difficult to discover.**

Therefore, our basic method of search is to drive a fast, wide-field camera at a rate expected to conform with the angular speed of a satellite across the sky. While this produces a long streak for each star in the field, the image of an actual satellite would appear on the film as a point or a very short trail. But since the angular speed of such a body would not be known in advance, the program calls for repeated surveys of each sky area with the camera driven at many different tracking rates.

The hunt was begun with an 8½-inch f/1.6 Schmidt camera, made many years ago by the amateurs Charles and Harold Lower, mounted on the Lowell 13-inch photographic refractor. (The latter instrument had been used by Mr. Tombaugh for the discovery of the planet Pluto in 1930.) The telescopes were fitted with a Graham variable-speed transmission drive, allowing the tracking of satellites at any angular velocity and, therefore, at any desired distance from the earth.

During the next two years of the search, two K-24 aerial cameras of 2.8-inch aperture with Ektar f/2.5 lenses were added, in order to obtain continuous orbital coverage for the close-in zones having higher angular drive rates than the Schmidt could achieve. But at such high rates of motion, the slit of the 13-inch dome could not be moved fast enough to keep in front of the cameras, so all three were remounted under a roll-off roof, as shown in Fig. 2.

Many unusual phenomena were observed visually or recorded on film during the long, cold nights of the satellite patrol at Flagstaff. One evening a 3rd-magnitude

**Fig. 2. The 8½-inch Schmidt camera is on the left side of the mounting, the K-24 cameras on the right, with the roof of the shelter rolled back.**

* "Proposed Geodetic Triangulation From an Unmanned Orbital Vehicle by Means of Satellite Search Technique," Clyde W. Tombaugh, *Journal of the American Rocket Society*, *25*, *232*, May, 1955.

orange light moved noiselessly from north to south, appearing to be slowly falling; it proved to be the jet flame of a high-flying aircraft without apparent navigation lights. Some films recorded strange zigzag lines of light; these were meteorological balloons being released at night for seeing studies by the Naval Observatory's Flagstaff station (see page 4, November, 1956, *Sky and Telescope*).

One morning in May last year, strange lights were noticed that hovered in formation just above the treetops, and then moved on silently; personnel at the Naval Observatory station also noted the phenomenon, which fitted the description of the so-called Lubbock lights. They appeared the next morning at nearly the same time, but seemed to move faster, as if closer to us. This time they recalled a past experience of mine—they looked and acted like a squadron of helicopters! This explanation was later confirmed.

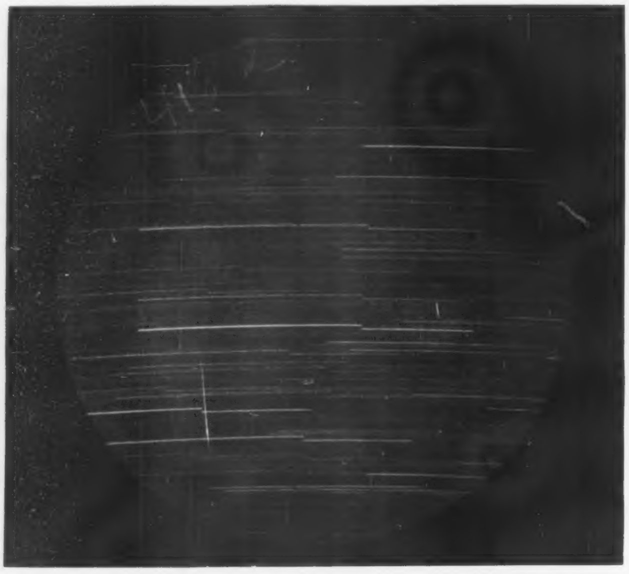


**Fig. 3. A contact print of a typical three-minute search exposure with the Schmidt camera, on April 19, 1955. The driving rate of the camera was 190 degrees per hour. Note the declination offset, which divides each star trail into two parts. During the exposure, a bright meteor crossed the field (lower left); thickenings of its trail indicate bursts of light.**

Other night phenomena very frequently recorded on the satellite-search films were meteors. A typical trail is shown in Fig. 3, recorded by the Schmidt camera, but the most spectacular meteor was that of April 9, 1956, caught with one of the Ektar lenses during a regular five-minute exposure at a driving rate of 186 degrees per hour. (This driving rate would be expected to match the angular velocity of a satellite at a geocentric distance of about 7,000 miles, assuming a circular orbit.)

The offset between the first and second parts of the star trails in Figs. 3 and 4 is in declination only, made mechanically during the exposure without closing the shutter. The main purpose of the shift is to facilitate identification of images of a satellite. If the camera were to track at the exact apparent motion, the satellite images would be two dots, one above another, separated by the amount of the offset; such pairs of images would not be expected from film defects and other spurious effects. In the more likely event that the satellite images are themselves short trails, their relative lengths would give a measure of the object's distance from the earth.

The fireball of April 9th was of apparent magnitude $-3.5$ or $-4$, as bright as the planet Venus, and it left a luminous train visible for 14 minutes in the southern sky. This meteor appeared just above Phi Ophiuchi, and passed between Saturn and Beta Scorpii into Libra. After occulting the star 42 Librae, it began to flash intermittently, and finally burned out in a brilliant burst of light past Theta Centauri. The path is drawn in Fig. 5.

Fifteen seconds after the terminal burst, the Schmidt camera was turned on the luminous train and a picture (Fig. 6) was made in two parts: without drive for five seconds, then with a drive rate of 186 degrees per hour for one minute. It is evident that the train was quickly distorted by winds at different altitudes in the upper atmosphere. Its interpretation requires visualizing the effect of the rapid sweeping of the camera on the shape of the train, but with the aid of the star trails I found that the upper part of the train was moving northeastward at a rate of 1.1 degrees per minute of time.

The lower, west end of the meteor train is 3.7 degrees long, and appears to have had a westward drift of 0.8 degree per minute of time. As a whole, the luminous train seemed to have a counterclockwise rotation. Notice the start of a kink in the

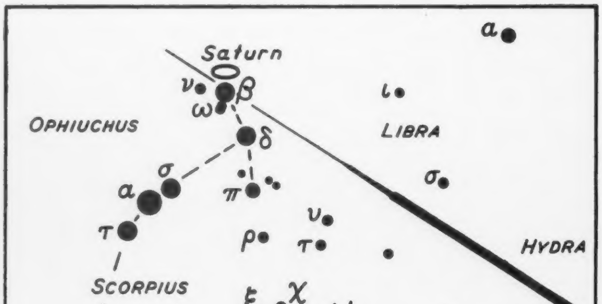



**Fig. 4 (left). This is the K-24 film that recorded the bright fireball of April 26, 1956, which appeared at 2:34:45 a.m., Mountain standard time. Note how the meteor suddenly became much brighter near the midpoint of its path. The stars whose trails appear in the photograph may be identified with the aid of Fig. 5 (right), which is a plot of the path of the fireball among the stars of the southern sky.**

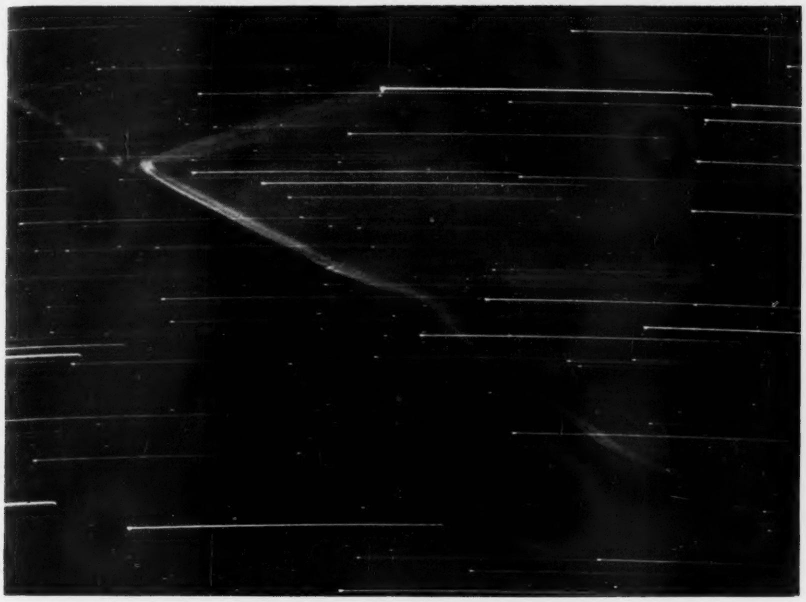


**Fig. 6. The luminous train of the fireball of April 26, 1956, from a one-minute Schmidt exposure that began 15 seconds after the fireball passed. For the first five seconds the camera was stationary, recording the train as the diagonal streak in this picture. Then the camera was driven at a rate of 186 degrees per hour, trailing the images toward the right. Parts of the fireball train show an upward displacement, due to winds aloft. Compare this with Fig. 7, showing the appearance of the train soon afterward.**

train caused by wind shear, probably at a height roughly 50 miles above the surface of the earth.

Another Schmidt exposure (Fig. 7) was made 2 minutes 15 seconds after the fireball's final flash occurred. The luminous train had now become much dispersed and distorted by the upper winds into a fan-like structure. The upper end of the train was blown northeast, the center slightly to the north, while the lower end was blown westward. This effect could have been caused by differences among the winds at various altitudes.

With observations made at only one site, there was no way of measuring the height of this sporadic meteor. It is hoped that some observer in another part of Arizona may have seen and recorded this object; other reports would be welcome in order to calculate the absolute heights and wind velocities.

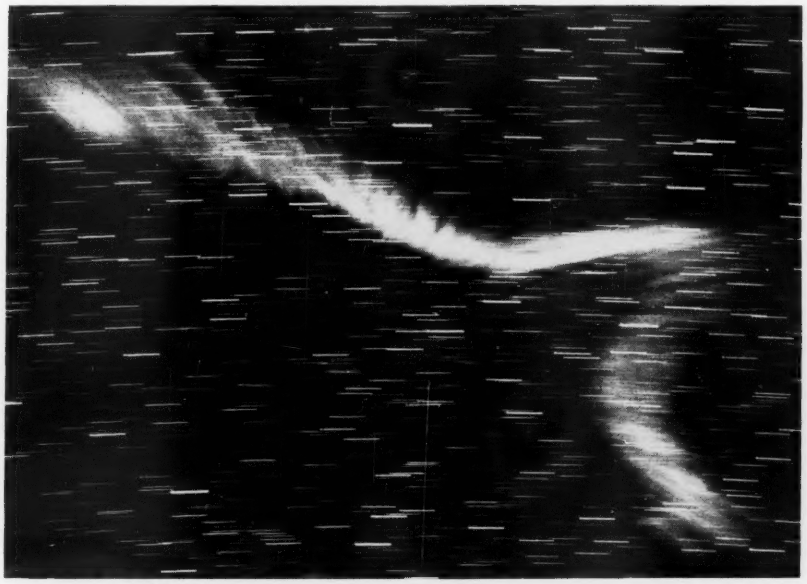


**Fig. 7. The Schmidt camera was used without drive for this one-minute exposure of the train of the same fireball, $2\frac{1}{4}$ minutes after the meteor disappeared. The inconspicuous kink of Fig. 6 is now very noticeable at the right.**

### *MINOR PLANET GEOGRAPHOS*

One of the unusual asteroids found with the 48-inch Schmidt telescope during the National Geographic-Palomar Observatory sky survey (page 107, January issue) has been named *Geographos* by its discoverers, R. Minkowski and A. G. Wilson. It is also known as minor planet 1620, although after its discovery on August 31, 1951, it was temporarily designated 1951 RA; the permanent number was not assigned until later, when its orbit became well-enough known to insure its recovery in future years.

Requiring only 17 months to complete one revolution around the sun, Geographos moves in a path whose perihelion point lies near the orbit of Venus. When farthest from the sun, the minor planet is a little outside of the orbit of Mars. Probably not much over a mile in diameter, this faint asteroid can be observed only when it passes near the earth.

According to computations by S. Herrick, Jr., and C. Hilton of the University of California at Los Angeles, Geographos will approach within four million miles of the earth in 1969, closer than any other minor planet of known orbit. Observations of the asteroid at that time can be used to determine the distance scale of the solar system. Our presently accepted value of the distance from the earth to the sun is based on similar observations of another asteroid, Eros, which approached within 16,200,000 miles in 1931.

### *GLASS LIGHT FUNNELS*

The usefulness of large telescopes would be much increased if the great wastage of light in stellar spectrographs could be avoided. When the 100-inch reflector is used in poor seeing, the disk of a star's image is so large and unsteady that only about four per cent of the light actually passes through the narrow slit of the spectrograph. To overcome this defect, many years ago an "image slicer" was invented by I. S. Bowen, who is now director of Mount Wilson and Palomar Observatories, but practical difficulties hindered its use at the telescope.

N. S. Kapany, University of Rochester, has proposed a light funnel made of a bundle of glass fibers. These are clamped in circular form at one end to receive the star's light; at the other end they are clamped in the shape of the spectrograph slit. Light is "piped" through each fiber by total internal reflection. Absorption and other light losses are theoretically about five per cent in a funnel three inches long, so an increase in the efficiency of a spectrograph seems possible by this method.

Extensive laboratory tests have been made of this principle at the University of Rochester's Institute of Optics. Even though the same difficulties that hampered the image slicer may preclude use of the light funnel in stellar spectrographs, there are many other possible applications in science and technology.

# NEWS NOTES

### *REMOTE GLOBULAR CLUSTER*

A faint and inconspicuous object near the boundary of Ursa Major and Leo has turned out to be a globular cluster far outside the limits of the Milky Way, deep in intergalactic space at a distance from us of about 475,000 light-years. The object is No. 4 in a list of 13 faint globulars published by George O. Abell during his study of sky survey plates taken with the 48-inch Schmidt camera at Palomar Observatory.

Using blue and red plates of the survey, Dr. S. van den Bergh, Göttingen University Observatory, has measured approximate magnitudes and colors of 19 stars in Abell No. 4. By assuming this globular to have similar characteristics to such well-studied objects as M3 in Canes Venatici, he could estimate the distance, making allowance for interstellar absorption of the cluster's light. His results appear in the October, 1956, *Publications* of the Astronomical Society of the Pacific.

### *DIAMETER OF SIRIUS*

A novel type of stellar interferometer has been tested by successful measurement of the angular diameter of the star Sirius, at the Jodrell Bank Experimental Station of the University of Manchester, England. R. Hanbury Brown and R. Q. Twiss describe their work in the November 10, 1956, issue of the British journal *Nature*.

In these experiments, two searchlight mirrors 61 inches in diameter were pointed at Sirius. The photons of a star's light collected by such a mirror arrive at a fluctuating rate. If the second mirror is placed immediately alongside the first, the photons it collects will have identical fluctuations in their rate of arrival. But when the mirrors are several yards apart, the correlation between the two sets of fluctuations is reduced by an amount that depends on the angular diameter of the star.

At Jodrell Bank, an RCA 6342 photomultiplier tube was placed at the focus of each searchlight mirror; the photocurrents were amplified and the outputs multiplied together in a linear mixer; and the average value of the product was recorded on the revolution counter of an integrating motor. The readings of this counter gave a direct measure of the correlation between the intensity fluctuations in the light received at the two mirrors.

During the winter of 1955-56, a total of 18 hours of such observations were made on Sirius, with mirror separations of up to 30 feet. The diameter of the star was found to be 0.0068 $\pm$ 0.0005 second of arc, agreeing well with the angular diameter of 0.0063 second computed from the known surface temperature and brightness of Sirius.

This new type of interferometer can be used to measure the diameters of other bright stars, according to the designers. Mirrors at least 20 feet in diameter will be needed for stars as faint as magnitude +3, but the mirror surfaces need not be of optical quality, and searchlight reflectors can serve. It may be possible to employ base lines of hundreds or even thousands of feet.

The new method is analogous to one already used at Jodrell Bank with radio receivers for determining the angular diameters of cosmic radio sources. Its fundamental distinction from older stellar interferometers of the Michelson type (such as the ones used at Mount Wilson Observatory many years ago) is that the latter utilize the phase relationships in two beams of light from a star, while the new method depends on the intensity relationships.

### *SS CYGNI AS A BINARY*

The variable star SS Cygni is normally of magnitude 12, but at intervals averaging 50 days it suddenly brightens to about magnitude 8, returning a few days later to minimum brightness. It has long been a favorite with observers of variable stars.

In the *Astrophysical Journal* for September, 1956, Dr. A. H. Joy, Mount Wilson and Palomar Observatories, reports spectrographic observations that confirm SS Cygni is a close binary. One component is a dwarf yellow star, similar to the sun, and the other is a very underluminous blue star. The two revolve around their center of mass in a period of 0.276244 day.

During an outburst of SS Cygni, the faint dark lines of the yellow star's spectrum are drowned out by the strong continuous spectrum of the hot star, which also has broad emission lines. At minimum light, however, Dr. Joy was able to measure the velocity shifts of the exceedingly faint absorption lines. He also used the bright lines of the hot star, even though these are too wide for accurate measurement. Nevertheless, the period determination was a good one, because on each of five nights several spectra had been taken in succession.

### *BOK RESEARCH PRIZE*

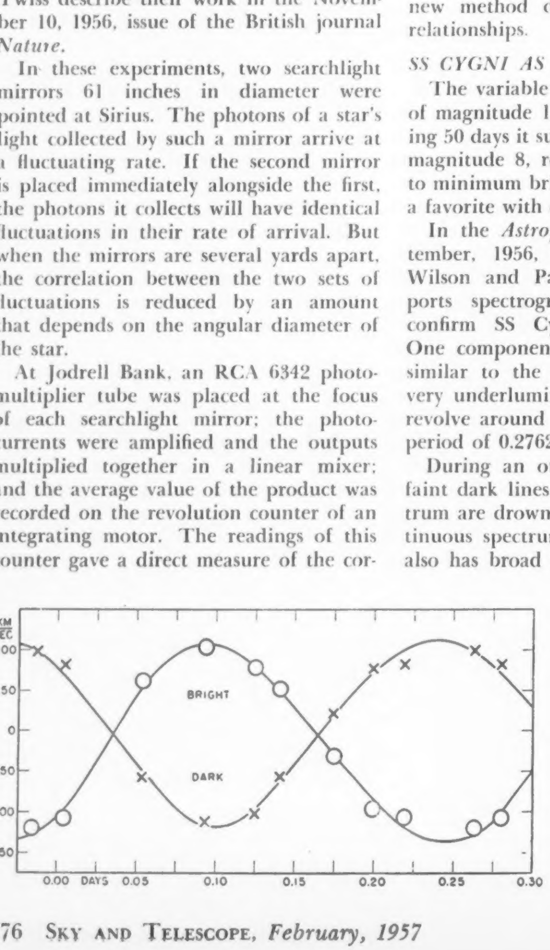
Harvard University has announced the establishment of a prize to encourage Milky Way research, from a $6,000 fund provided by an anonymous donor to honor Bart J. Bok. Every two years, the fund's income will be awarded to a physical scientist with a recent doctorate from Harvard or Radcliffe, to recognize observational research on the Milky Way.

As a Harvard Observatory staff member since 1929, Dr. Bok has made major contributions to the study of our galaxy and to radio astronomy. In January of this year he left to become director of the Mt. Stromlo Observatory of the Australian National University.

**IN THE CURRENT JOURNALS**

THE NATURE OF THE TYPICAL LUNAR MOUNTAIN WALLED PLAINS, by Dinsmore Alter, *Publications*, Astronomical Society of the Pacific, October, 1956. "These data indicate strongly that typical mountain walled plains . . . are not due primarily to explosions either from internal or from external causes."

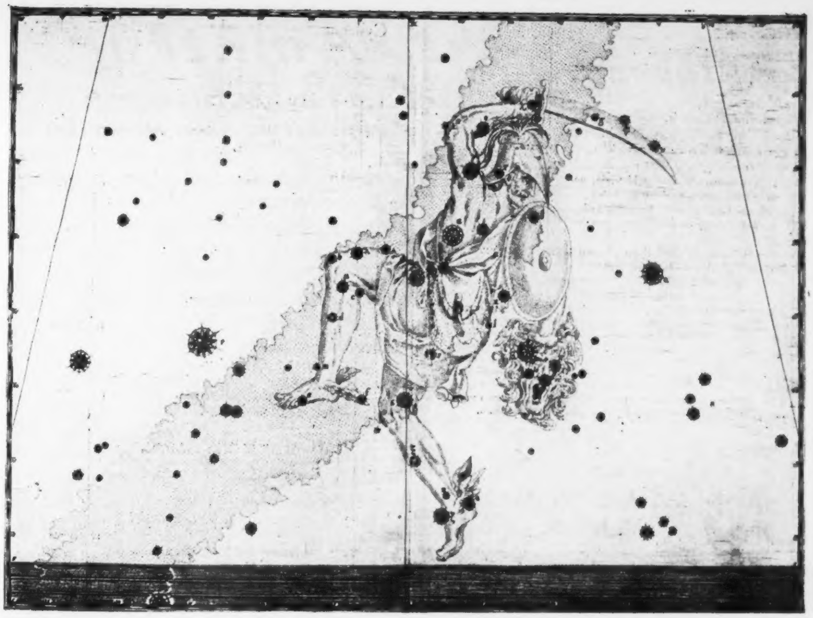
THE NEWEST SYNTHETIC ELEMENTS, by Albert Ghiorso and Glenn T. Seaborg, *Scientific American*, December, 1956. "The discovery of element 101 was especially exciting because it was identified on the basis of only a couple of atoms, produced by transmutation in an amount of target material so small that it was unweighable."




**A. H. Joy's radial-velocity curves for the binary star SS Cygni. When the dark-line star approaches us at its maximum rate, 115 kilometers per second, the bright-line star is receding at 122 kilometers per second. Each point is the mean of three or four observations. From the "Astrophysical Journal."**

# Why Did the Arabs Call Beta Persei "al-Ghul"?

GEORGE A. DAVIS



**Perseus, as he appears in Bayer's "Uranometria." Algol is the star marking the left eye of the head of the Gorgon, Medusa, which the hero carries.**

GEMINIANO MONTANARI of Modena, Italy, professor of mathematics at the universities of Bologna and Padua, was the first to notice the light variations of Beta Persei. He watched it more or less regularly from 1667 to 1669; and then, on November 8, 1670, he observed the first minimum of Algol of which any record still exists.

Much has been written since then to the effect that the name, *al-Ghul*, is conclusive proof that the ancient Arabs were familiar with the star's variability. The following extracts from the writings of several modern astronomers will show what the general belief has been.

"The variability of this remarkable star was first scientifically noted by Montanari in 1670, but it is tolerably clear that these light variations had been detected long before his day. Indeed, the winking of this star, so to speak, probably influenced those who christened it, so that they likened it to the eye of some great demon peering down through space seeking his prey."

". . . Algol, known since 1667, but probably recognized as variable by the Arabs many centuries earlier."

"The Arabians were keen observers of this star, for by the name they gave it, they were undoubtedly aware of its flickering light, like an eye opening and partly closing."

"Since the star's variability in brightness was not understood, it seemed terrifying, and the superstitious Arabs imagined it to be the eye of a demon."

"It is hard to explain in any other way the very appropriate name which the Arabs gave it."

It should always be remembered, when studying the star names of the Arabs, that their astronomy generally falls into two very distinct categories. First, we have the names of stars and asterisms that are purely indigenous to the ancient Arabs, uninfluenced to any appreciable extent by the astronomy of other peoples. Second, we have the Arabic names of the constellations and stars taken from Greek astronomy as represented by Hipparchus and Ptolemy, which, of course, is ultimately Sumerian and Akkadian in origin.

Strange as it may seem, we have here the peculiar situation of dealing with the constellation of Perseus as described by Ptolemy, in which we find the head of Medusa, and with an ancient Arabic conception in no way associated originally with the stars, but which finally became part of their conception of Perseus as the head of the ghul. Beta Persei, therefore, as described by Ptolemy is "the bright one of those in the head of the Gorgon," and as described by the Arabs, is "the bright one in the head of al-Ghul."

Before describing the ancient conceptions of Medusa and the order of the jinn commonly known as the ghul, let me make one more point clear. The ancient Arabs peopled their sky with sheep, goats, kids, calves, camels, wild asses, frogs, lions, wolves, hyenas, fish, ostriches, biers, thrones, cooking pots, millstones, ladders, buckets, necklaces, deserts, ponds, and the like—in other words, with familiar living creatures and objects that belonged to their culture and experience. Nothing purely imaginative, such as demons, goblins, fairies, or jinn, is included in their sky. In their later astronomy patterned after Ptolemy, however, when a substitute was sought for the strange Greek mythological figure of Medusa's head, the Arabs looked for an equivalent from their own mythology.

According to the older Greek art, the head of Medusa, commonly called the *Gorgoneion*, was a horrible thing, an awful monster, grinning terribly, with flat nose, lolling tongue, tusk-like teeth, staring eyes, and serpents in her hair and girdle. Her most formidable weapon was her power to turn to stone any one who looked upon her.

The Arabs, of course, were acquainted with this foreign description of Medusa. Did they have anything in their mythology to match this conception? They certainly did. The ghul was a female demon and sorceress, who assumed on occasion various monstrous shapes and forms; she ate men and corpses; she haunted burial grounds, deserts, woods, and other sequestered spots; and she would kill and devour any human creature who had the misfortune to fall in her way. She would appear to a person traveling alone in the night and, in the guise of a fellow traveler, would lure him out of his way to his destruction. Finally, she was believed to be a daughter of Allah, but created out of fire instead of clay.

I do not know which conception is the more gruesome and terrible, the head of Medusa or the head of the ghul! It seems to me as though the Arabs in this case actually out-heroded Herod! At any rate, they chose the ghul as their nearest approximation to the Gorgon, and not because of the variability of the star's light, of which they were entirely ignorant. There is no direct evidence of any kind, either in the literature of the Arabs or in that of any other country, of the star's variability prior to the year 1667. The Arabs, therefore, instead of regarding Perseus as "bearing throat-severed the Gorgon-fiend's head," called him *Hamil Ra's al-Ghul*, "the bearer of the demon's head," as being something they could readily recognize and understand.

Since we have clean-cut evidence of the excellent observational powers of the ancient Arabs, this result is, of course, disappointing; but it is one we are bound to accept until new evidence to the contrary is forthcoming.

# *Amateur Astronomers*

### THIS MONTH'S MEETINGS

**Dallas, Tex.:** Texas Astronomical Society, 8 p.m., Lone Star Gas Co. auditorium. Feb. 25, Mrs. Mary A. Ferraro, "Flying Saucers."

**Louisville, Ky.:** Louisville Astronomical Society, 8:30 p.m., University of Louisville, Natural Science building. Feb. 5, Dr. E. C. Rust, Southern Baptist Theological Seminary, "The Expanding Universe."

**New York, N. Y.:** Amateur Astronomers Association, 8 p.m., American Museum of Natural History. Feb. 6, Dr. Jan Schilt, Rutherfurd Observatory, "The Cosmic Distance Scale."

**Santa Ana, Calif.:** Orange County Amateur Astronomers, 7:30 p.m., home of Ralph Brower, 1101 N. Franklin. Feb. 5, Mr. Brower, "Telescopes and Their Uses."

**Springfield, N. J.:** Amateur Astronomical Society of Union County, 8 p.m., Regional High School. Feb. 22, William A. Cassidy, Pennsylvania State University, "Down Under and Back Up: A Meteoritical Odyssey."

**Washington, D. C.:** National Capital Astronomers, 8:15 p.m., Commerce Department auditorium. Feb. 2, Dr. B. F. Burke, Carnegie Institution of Washington, "Radio Signals from Other Planets."

### TULLAHOMA, TENNESSEE

The Tullahoma Astronomy Club, which recently observed its second anniversary, is comprised of seven juniors. The club has a 2.4-inch refractor and is making a 6-inch reflector. The group's main project is meteor observing. A weekly newspaper is also printed by the members. Billy York, Rte. 2, Box 5, Tullahoma, Tenn., is president and would appreciate correspondence from other junior clubs.

### SAO PAULO, BRAZIL

Last August, a group of Brazilian amateurs interested in the moon formed a new organization, the "Sociedade Brasileira de Selenografia," to encourage lunar observations. The society publishes a bulletin *Selene*, of which the first issue, in four pages, appeared in November. Written in Portuguese, this publication is edited by Rubens de Azevedo, Caixa Postal 9011, Sao Paulo, Brazil.

### FOUNDER HONORED AT 20TH ANNIVERSARY AT MOLINE

About 300 members and friends paid tribute to the Popular Astronomy Club's founder and president, Carl H. Gamble, of Moline, Illinois, at the society's 20th-anniversary dinner meeting last October. Among the congratulatory messages was one from President Eisenhower.

Dr. Gamble has been an amateur astronomer since 1930, and in 1938 he built his Sky Ridge Observatory, where the society holds its regular meetings. The observatory is also opened upon request to the public.

In reviewing the history of the club, Dr. Gamble said that the purpose of the organization is to popularize knowledge of the universe, and he estimated that he has given 1,053 astronomy talks before 75,000 persons in the past 20 years.

During the program Dr. Gamble was presented with a sidereal clock and matching solar clock by members of the club.

### CHARLOTTE, NORTH CAROLINA

The Charlotte Amateur Astronomers Club, which recently celebrated its second anniversary, now has 42 active members. Its current meetings are devoted to an astronomy film program, a lecture by Dr. William Calder of Bradley Observatory, and a trip to the University of North Carolina. The society had a field trip to the Leander McCormick Observatory of the University of Virginia.

Officers for the coming year are: Forest T. Selby, president; Mrs. Charlotte Kelly, vice-president and program chairman; Mrs. Preston Nowlin, secretary; and Frank Williams, treasurer. The club is a member of the Astronomical League.

### LEMONT, ILLINOIS

On October 8, 1956, the Argonne Astronomy Club was formed. The club is composed primarily of Argonne National Laboratory personnel, but membership is open to everyone. Meetings alternate between the third Wednesday and third Friday of each month. Officers are: Homer DaBoll, president; Donald Engelkemeir, vice-president; and Marilyn Franzen, secretary-treasurer. Further information may be had from Miss Franzen, Argonne National Laboratory, P. O. Box 299, Lemont, Ill.

### NEW ORLEANS, LOUISIANA

The New Orleans Society for the Advancement of Astronomy has been very active since its formation last summer. We meet every Monday at 7:30 p.m. at private homes or make field trips.

We occasionally have a new members night, which consists of a program of slides and a lecture. Other meetings are devoted to home planetarium demonstrations, trips to Tulane Observatory, and scientific papers. Once a month we have an observing party for the public, at which we request donations to our club.

JOSEPH MICKEL
1307 Ridgelake Drive
Metairie, La.

# BOOKS AND THE SKY

## ROBERT HOOKE

Margaret 'Espinasse. University of California Press, Berkeley, 1956. 192 pages. $3.75.

AFTER APOLOGIZING for a lecturer in English (at Hull University, England) daring to write a biography of a scientist, the author explains that she was intrigued by reading the diary kept so meticulously by Robert Hooke. To Miss 'Espinasse a personality emerged very different from "the hostile tradition which depicts him as a quarrelsome eccentric, a nagger of greater men, an habitual claimer of rights which were not his." This led to extensive research. She has attempted in this short book (155 pages of reading matter) to give a truer picture of Hooke as a "brilliant, generous, unlucky man."

This reviewer recommends the book, however, on other grounds than as a vindication of the character of Hooke. Its attraction to most readers will lie in the vivid picture that it gives of science in the 17th century—that period when the appeal to observation and experiment was replacing the appeal to authority which had delayed the progress of science since classical times. The stirrings of a new spirit had already been felt in the work of Galileo, Vesalius, Gilbert, Kepler, and other leaders in the renaissance of science. Now it was really taking hold, and eminent British scientists were introducing the experimental method into many fields of work. Among these Robert Hooke was one of the busiest, most enthusiastic, and most successful.

The fields in which Hooke worked show an amazing spread—astronomy, optics, chemistry, meteorology, physiology, cartography, geology, botany are among them. His greatest genius was as a mechanical experimenter. As a student at Oxford University he became a research assistant to Robert Boyle. So useful did he prove to be in the laboratory that when the Royal Society was chartered in 1662, Boyle recommended him for appointment as curator of experiments, a post that he held for 40 years. He was instructed "to furnish the Society every day they meete [that was once a week] with three or four considerable experiments." His mechanical skill was enlisted by many other scientists to assist them in their research. The diary shows how Hooke's days and evenings were busily occupied with consultations and long discussions, often in coffee houses and taverns according to the custom of the day.

In addition to his experimental duties with the Royal Society (of which he eventually became secretary), Hooke was its Cutlerian lecturer in mechanics, and taught geometry in Gresham College. An appointment as a city surveyor in connection with rebuilding after the great fire of London, 1666, brought him into touch with Sir Christopher Wren. Hooke worked closely with Wren for a busy eight years as a kind of junior partner, not only in London but in connection with many buildings outside the city. He was both architect and supervisor of construction.

Miss 'Espinasse devotes a lengthy chapter to Hooke's social life. He knew everyone who was significant, having many contacts with King Charles II and with the king's cousin, that dashing military and naval leader Prince Rupert, both of whom were intensely interested in science. Hooke's diary is full of pungent appraisals of eminent men (Flamsteed, the first Astronomer Royal, is characterized as a "cockscomb," "proud and conceited of nothing," "an Ignorant impudent Asse"). Hooke's genius for mechanics led him, to the disapproval of his fellow members of the Royal Society, to include in his circle of friends many of the leading craftsmen of the day, whose practical skills appealed to him.

Probably Hooke's greatest scientific publication was the book *Micrographia*, illustrated by his beautiful drawings of what he had viewed through the microscope he had constructed himself (including the discovery of the cell struc-

ture of plants. An astronomical reader rather regrets that fuller mention is not made of his contributions to astronomy, such as improvements in making telescopes, the invention of the iris diaphragm, and of the balance spring for chronometers. He was the first to determine the rotation of Jupiter; he observed comets and eclipses from a turret observatory above his rooms in Gresham College.

Hooke's writings include many scientific intuitions that he had no time in his busy life to follow up. He believed in the variation of species, and suggested that geological chronology might eventually be founded on the changes in fossil forms in successive rock formations. He anticipated the true explanation of combustion by 100 years, while 18th century chemistry was dominated by the phlogiston theory. He proposed the first law of motion 13 years before Newton dealt with it in the *Principia,* and was convinced of the existence of gravitation, proposing its inverse square law in 1680 (though without proof).

These last intuitions led to Hooke's unfortunate controversy with Sir Isaac Newton over the lack of acknowledgment by the latter of Hooke's prior suggestions. The bitter squabble made enemies of these two leading spirits of the Royal Society. It is significant that Newton was not elected the society's president until a few months after Hooke's death. Miss 'Espinasse's book, while always according to Newton the greatness due him, is of value to anyone wishing to consider Hooke's viewpoint.

Wretched ill health plagued Robert Hooke all his life. The diary is dotted with menus of meals that actually agreed with him, but he used his own symptoms for scientific study. He even took advantage of his bouts of insomnia to make prolonged astronomical observations.

Any one of half a dozen aspects of Hooke's work should gain him an honored place in the story of the 17th century. His ill luck was that he was overshadowed by greater men—by Newton in science and by Wren in architecture. He was highly esteemed by most of his contemporaries, but was a forgotten man within a generation after his death in 1703. Now, two centuries later, a rediscovery of his worth has been made by historians of science, especially by E. N. da C. Andrade.

The book under review is a readable contribution to the rediscovery, so carefully documented that one feels confident of every statement made. The book brings to life that eager, excited period when modern science was being born. Science was not then divided into compartments. As one entry in Hooke's diary puts it, "Spent most of my time considering all matters." That was the kind of mind he had.

E. RUSSELL PATERSON
Sir George Williams College
Montreal, Canada

SMITHSONIAN ASTROPHYSICAL OBSERVATORY
BULLETIN FOR
Visual Observers of Satellites

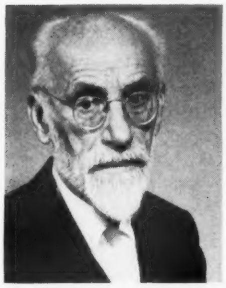
NUMBER 5 60 GARDEN STREET, CAMBRIDGE 38, MASS. FEBRUARY, 1957

# News from MOONWATCH Headquarters

## STEERING COMMITTEE

A steering committee has recently been appointed at the Smithsonian Astrophysical Observatory to provide scientific and technical advice in the MOONWATCH program, and to aid in co-ordinating its visual observations of artificial satellites with other parts of the optical tracking program.

The chairman of the new committee is Dr. George Van Biesbroeck, who recently joined the Smithsonian staff. For more than 40 years he has been well known as an astronomer at the Yerkes Observatory of the University of Chicago, actively engaged in observing double stars, comets, asteroids, and solar eclipses.



GEORGE VAN BIESBROECK

Other members of the committee are Dr. Joseph Ashbrook, researcher in variable stars at Harvard Observatory, as well as technical editor of *Sky and Telescope;* Dr. Don Lautman, head of the satellite computing center; Dr. G. F. Schilling, formerly program officer of the U. S. National Committee for the International Geophysical Year, and now a consultant on the Smithsonian Astrophysical Observatory staff.

## FLYBYS

Registered MOONWATCH teams can now look forward to conducting realistic test observing sessions in the near future with simulated satellites overhead. Arrangements were recently completed whereby the U. S. Air Force will provide "flyby" airplanes over stations in various parts of the country. By the time this *Bulletin* is published, it is expected that three stations in the Washington, D. C., area will have held at least one test session with such mock satellites.

The flybys will be unusually realistic. High-flying planes will cross over the observing stations at such altitudes that their jets will not be heard, nor will their navigation lights be seen. Each plane will carry a light which, seen from the ground, will match the apparent magnitude of the satellite. The course and speed of the aircraft will closely resemble the path and angular velocity of a satellite at a particular part of its orbit.

The altitude and cruising speed of one of the flyby aircraft should allow all MOONWATCH stations within a radius of 100 miles to be served by a single plane. Therefore, it will be the policy to have a plane assigned to a flyby mission pass over two or more stations in any one area.

Leaders of registered stations whose organizational work is well advanced may wish to request flybys for tests of their observing teams. All such requests are to be made through the Smithsonian Astrophysical Observatory in Cambridge, so that necessary co-ordination with nearby stations may be made.

## STATION OPERATIONS

With the developing of the MOONWATCH program, it has become necessary to assign a Smithsonian Observatory staff member in Cambridge to work closely with Dr. Armand N. Spitz, the coordinator of visual observations. Therefore, Leon Campbell, Jr., has been appointed to carry on this staff work as supervisor of station operations.

Mr. Campbell is the son of the late Leon Campbell, who devoted 50 years to variable star research on the staff of Harvard College Observatory and was recorder of the American Association of Variable Star Observers.

LEON CAMPBELL, JR.

Meanwhile, Dr. Van Biesbroeck, who has been working with the Smithsonian staff in Cambridge, is soon to become available as an expert consultant to assist MOONWATCH teams in the Middle West and the southwestern parts of the United States. He temporarily will make his headquarters at Yerkes Observatory, returning to Cambridge periodically to continue his satellite work.

Advice in problems of station organization and operations, as well as in observing techniques, can be obtained from Dr. Van Biesbroeck and Mr. Campbell. Registered MOONWATCH teams who are desirous of having Dr. Van Biesbroeck visit their stations should invite him through the Supervisor of Station Operations for MOONWATCH, Smithsonian Astrophysical Observatory, Cambridge 38, Mass.

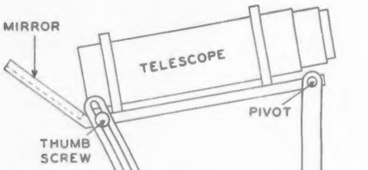
*The convenience of table-top observing is illustrated by this picture of Miss Martha Holt using an experimental MOONWATCH telescope constructed in the shops of the Smithsonian Institution. The mounting is made entirely of aluminum. The telescope's bed-plate has a rigid extension inclined at 45 degrees to carry the front-surface mirror.*

## XI. Table-top Observing with Telescopes Pivoted at Their Eyepieces

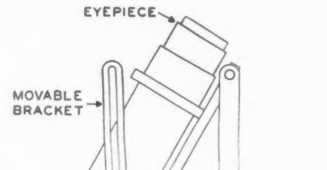
In *Bulletin* No. 3, Section VII, the optical parts of a simple MOONWATCH telescope were described, without details of how the instrument might be mounted. On the first page of that *Bulletin,* a model shows the instruments set up on posts in the line of the meridian, north and south of a central observing mast.

In the pictures of the experimental station at Silver Spring, Maryland, in *Bulletin* No. 4, the telescopes are shown mounted at their lower ends, each horizontal pivot being in the plane of the 45-degree reflecting mirror. This arrangement requires that the posts have different heights, because there is a large change in the position of the eyepiece when a telescope is turned from observing nearly overhead (lowered eyepiece position) to a part of the meridian having a large zenith distance (raised eyepiece position).

The diagrams show an arrangement in which the telescope rests on a plate pivoted at its upper end. When mounted this way, the eyepiece stays at practically the same height, regardless of the zenith angle at which the telescope is pointed. The lower end is supported in a slotted bracket, on which may be




*Two sketches show the advantage of mounting a MOONWATCH telescope so the fixed pivot is at the eye end of the instrument. At the left, the line of sight is toward an altitude of 80 degrees (10 degrees from the zenith) while the right-hand instrument is pointed to 30 degrees elevation; nevertheless, the height of the eyepiece above the table top or pier is practically the same in both cases.*



marked positions corresponding to various elevations of the sighting line.

When a mast is used as a meridian mark, there may be the drawback that its image is not exactly in focus with the stars, so the satellite's transit may be affected by an uncertain parallax, depending on the observer's eye. Thus, it follows that the function of the mast could be carried out by a metal strip or wire, about 1/8 inch in diameter, fastened a little in front of the field lens of the eyepiece so it appears in sharp focus. This gives a well-defined mark in focus with the stars; the wire will occult the satellite when it crosses the meridian, just as the mast would.

The picture below shows the wide-angle eyepiece removed from an experimental MOONWATCH model. The wire should be 1/8 inch above the eyepiece's inner rim. (This model is mounted with the pivot at the lower end; there was no photograph available of a model with the pivot at the eyepiece end.)

But if every telescope at a station contains its own internal reference line, the instruments need no longer be arranged in a single north-south row; the observers could sit side by side with their telescopes on level tables. At an ordinary-sized table three observers could sit on one side and two opposite, leaving one space for the lowest line of sight.

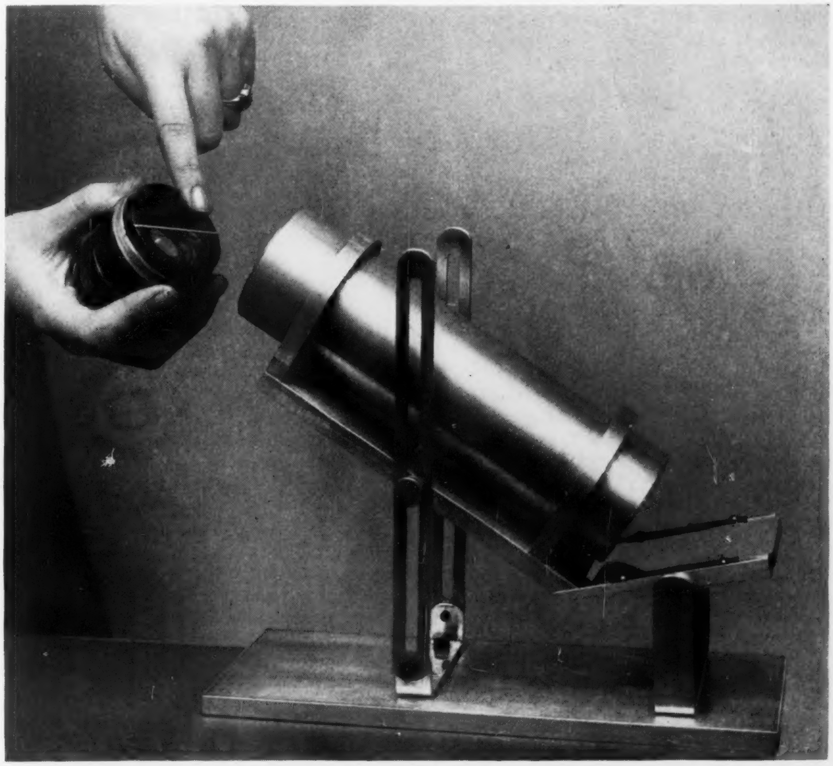
As in any other arrangement of observers, accuracy in aligning each telescope to the meridian is very important. As long as the telescopes are mounted *parallel* to one another, pointing in a north-south direction, each of them will define the meridian of the station. The parallelism may be achieved with guides made of slats fastened to the table, or with grooves. The table must be accurately horizontal, and the guides accurately oriented in azimuth.

Table-top observing is an answer to the problem of limited available space, especially on the roof tops of smaller buildings and in urban areas. There is no particular way in which tables need be grouped—they can be placed wherever the convenience of the observers is best served, as long as they are all within about 50 feet of the point for which the station's geographical position has been determined.

GEORGE VAN BIESBROECK

NOTE: The policy of the MOONWATCH program is always to allow the greatest possible scope and initiative to the efforts of each team to secure the desired observational data. The *Bulletin for Visual Observers of Satellites* will continue to present alternative methods for accomplishing the primary objective: to determine the position of the satellite within a minute of arc, and when it occupied that position to a second of time. There are obviously many approaches to problems of instrumentation and station arrangement. We wish to encourage groups to try other variations than those included in the bulletins, and to select the methods that seem most suitable.

A suggestion similar to Dr. Van Biesbroeck's proposal of a reticle had been considered earlier by the National Advisory Committee, which decided that the use of a meridian mast offered simpler and more permanent adjustments. In the committee's opinion, parallax should not be a serious difficulty with a mast. Nevertheless, the careful use of reticles should be an effective technique.—J. Allen Hynek, Associate Director and in charge of the Satellite Tracking Program.



*Instead of using a mast to define the meridian of a MOONWATCH station, a wire may be installed in the focal plane of the eyepiece, as shown in this photograph. The thickness of the wire is about $\frac{1}{8}$ inch, giving a perceptible time interval during which a satellite would appear to be occulted while passing across the meridian. This model of the telescope is mounted with its altitude pivot in the plane of the mirror, whereas a more convenient mounting is shown by the diagrams opposite.*

## REGISTRATION OF MOONWATCH STATIONS

When this issue of the *Bulletin* went to press, on January 5, 1957, a total of 40 MOONWATCH stations had been officially registered by the Smithsonian supervisor of station operations.

This number represents only those groups that actually have filed the proper information, which has been duly processed and accepted. There are numerous other stations in various stages of organization whose registration is expected in the immediate future.

Leaders of teams that have not yet registered are reminded that their applications for registration should be forwarded as soon as their basic plans are completed; it is not necessary to wait until every last detail is in hand.

The accompanying listing of registered teams shows an ocean-to-ocean coverage, but it also reveals that the area comprising Texas, New Mexico, Arizona, and parts of California, is very sparsely represented by registered groups. For this reason, a special plea is being made to amateurs and institutions in this section of the country to organize MOONWATCH teams. The California-Southwest band is vitally important because the satellite is expected, on its earliest orbital revolutions, to cross over this territory. Early visual detection of the satellite after launching is imperative, especially if the Minitrack radio transmitter in the satellite fails to operate.

At present, it appears probable that the first nationwide MOONWATCH test alert will be held in the early spring, when the weather in many parts of the country will have moderated and a larger number of stations have registered. Meanwhile, individual stations should continue periodic practice sessions in anticipation of the alert. It is recommended that station leaders and key members of observing groups refer to previous bulletins for general information concerning conducting observations and making reports during an alert. (*Bulletin* No. 4 contains such information concerning the postponed alert of December 8th.)

Copies of previous bulletins can be sent to any station leader or observer on request, as well as to all persons, groups, institutions, commercial organizations, and scientists interested in setting up MOONWATCH teams or assisting others to do so.

LEON CAMPBELL, JR.
Supervisor of Station Operations for MOONWATCH

MOONWATCH TEAM REGISTRATIONS

| *Location* | *Leader* | *Address* |
|---|---|---|
| Sylacauga, Ala. | B. L. Merkel | Rte. 1, Box 367, Sylacauga, Ala. |
| Phoenix, Ariz. | Amos Hoff | 1750 E. Desert Pk. Dr., Phoenix, Ariz. |
| Los Altos, Calif. | Roy Griffin, Jr. | 12566 Knoll Dr., Los Altos, Calif. |
| Oakland, Calif. | Frank Kelly | 361 Via Manzanas, San Lorenzo, Calif. |
| Sacramento, Calif. | Arthur Leonard | 269 Douglass Ave., Davis, Calif. |
| San Francisco, Calif. | Alfred J. Jensen | 2361 Union St., San Francisco, Calif. |
| Stockton, Calif. | C. P. Custer | 155 E. Sonoma Ave., Stockton, Calif. |
| Whittier, Calif. | Gary A. McCue | 7855 Euclid Ave., Whittier, Calif. |
| Denver, Colo. | Ken Steinmetz | 1680 W. Hoye Place, Denver, Colo. |
| Washington, D. C. | Robert Dellar | Rte. 1, Box 165-M, Springfield, Va. |
| Lakeland, Fla. | Warren Scholl | P. O. Box 2328, Lakeland, Fla. |
| Decatur, Ga. | L. B. Abbey, Jr. | 822 S. McDonough St., Decatur, Ga. |
| Hapeville, Ga. | Robert Grantham | Rte. 3, College Park, Ga. |
| Idaho Falls, Idaho | Roy R. Lee | 796 Saturn Ave., Idaho Falls, Idaho |
| Danville, Ill. | Everett Oliver | 504 Harvey St., Danville, Ill. |
| Lemont, Ill. | William B. Doe | 5631 Peck Ave., La Grange, Ill. |
| Peoria, Ill. | R. P. Van Zandt | 110 N. Parkside Dr., Peoria, Ill. |
| Des Moines, Iowa | Dale Cruikshank | 3655 67th St., Des Moines, Iowa |
| Manhattan, Kans. | Walter Houston | Rte. 3, Manhattan, Kans. |
| New Orleans, La. | Wendel Adam, CSC | 4950 Dauphine St., New Orleans, La. |
| Sedalia, Mo. | Russell C. Maag | 904 S. Ohio, Sedalia, Mo. |
| Albuquerque, N. M. | Mrs. Vi Hefferan | 215 7th St., N.W., Albuquerque, N. M. |
| Los Alamos, N. M. | Burton Masters | 1932-B 32nd St., Los Alamos, N. M. |
| Millbrook, N. Y. | Neale E. Howard | Millbrook School, Millbrook, N. Y. |
| New York, N. Y. | Harry L. Bondy | 61-30 157 St., Flushing, N. Y. |
| Charlotte, N. C. | Forest T. Selby | 200 S. Laurel Ave., Charlotte, N. C. |
| Greensboro, N. C. | George Phillips | 913 Spring Garden St., G'sboro, N. C. |
| Cincinnati, Ohio | Elmer Rahmes | 2594 Mack Rd., Hamilton, Ohio |
| Columbus, Ohio | Steadman Thompson | 1174 Broadview Ave., Columbus, Ohio |
| North Canton, Ohio | Richard Emmons | 313 Donner Rd., North Canton, Ohio |
| Tulsa, Okla. | James Westphal | 3407 W. 40th St., Tulsa, Okla. |
| Chambersburg, Pa. | Stanley Whitehill | 106 Franklin Farms Lane, Ch'burg, Pa. |
| Pittsburgh, Pa. | Robert Schmidt | 101 Clara St., Pittsburgh, Pa. |
| State College, Pa. | D. C. Whitmarsh | 219 E. Irvin Ave., State College, Pa. |
| Yankton, S. D. | Shapleigh Howell | Yankton College, Yankton, S. D. |
| Chattanooga, Tenn. | Llewellyn Evans | 68 S. Crest Rd., Chattanooga, Tenn. |
| Edinburg, Tex. | Paul R. Engle | 1601 Whitewing Dr., McAllen, Tex. |
| Arlington, Va. | D. Saltus | 5433 8th Rd., South Arlington, Va. |
| Harrisonburg, Va. | Robert Lehman | Eastern Mennonite Coll., H'burg, Va. |
| Roanoke, Va. | H. R. Klink | 2225 Woodcliff Rd. S. W., Roanoke, Va. |

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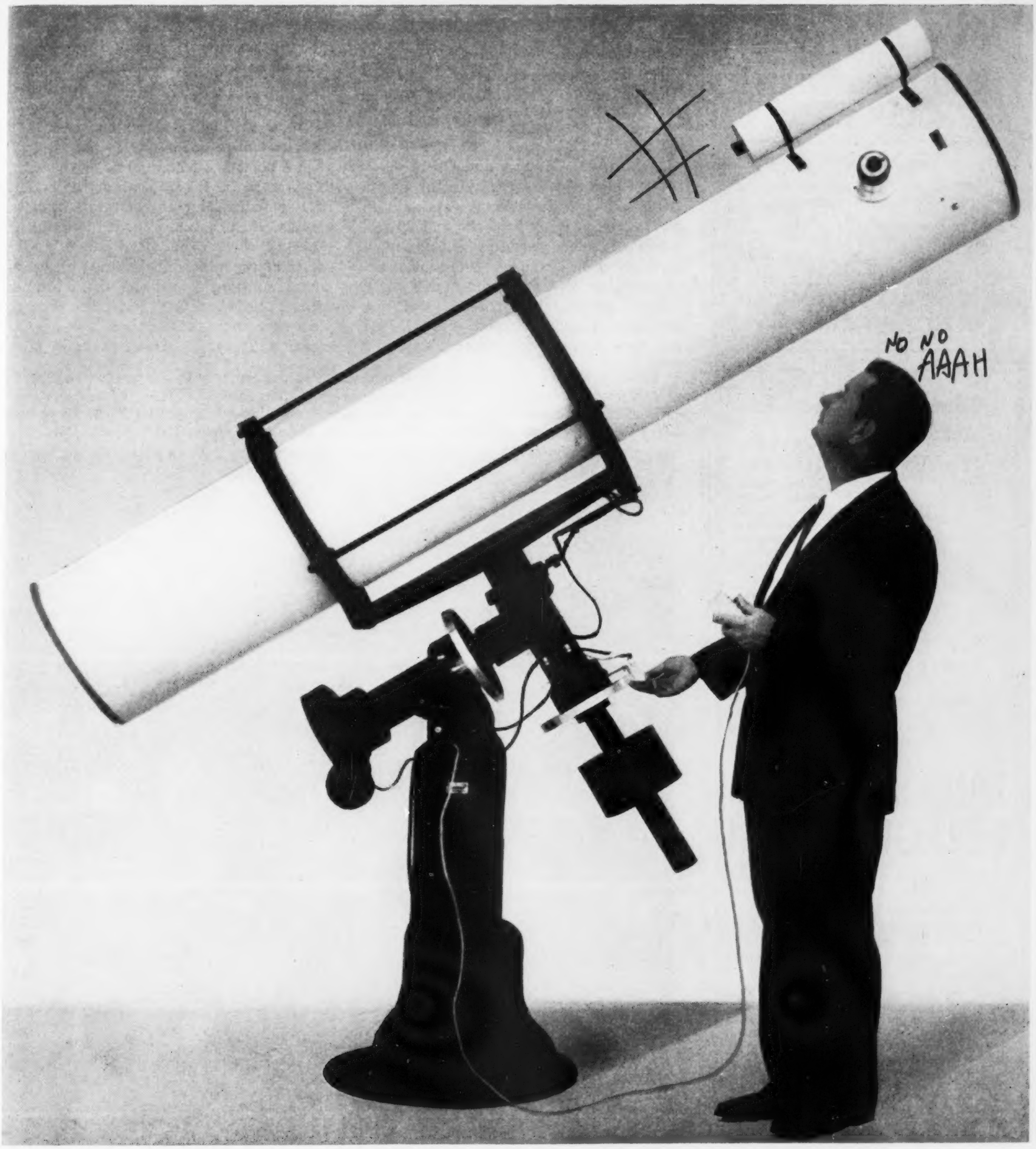
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## ERGEBNISSE UND PROBLEME DER SONNENFORSCHUNG

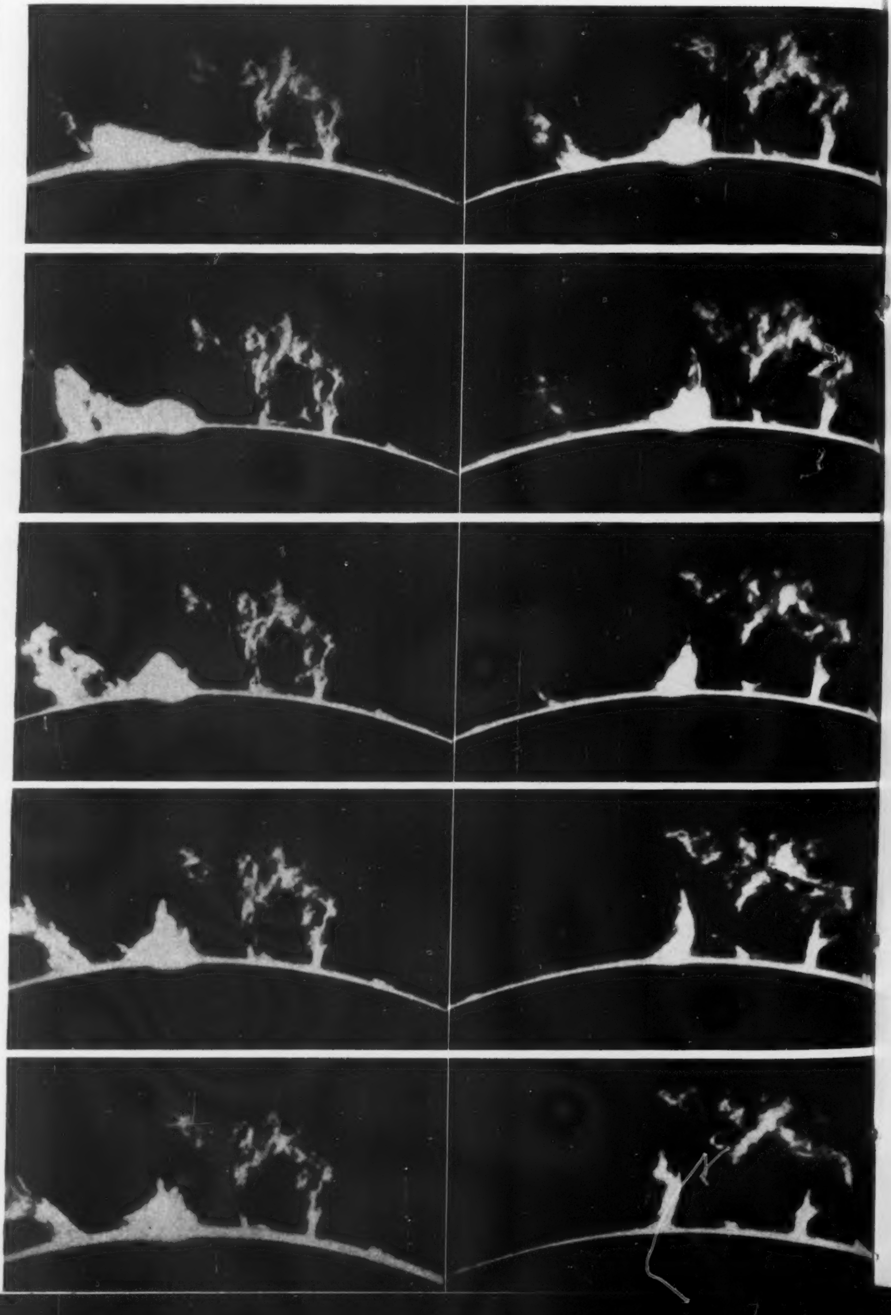
**M. Waldmeier.** Akademische Verlagsgesellschaft, Sternwartenstrasse 8, Leipzig C1, East Germany, 1955. 389 pages. DM 38.

THE APPEARANCE of the second edition of "Results and Problems of Solar Research," by the director of the astronomical observatory at Zurich, makes available to students and investigators of solar problems a well-known textbook with extensive compilations of observations and facts about the sun.

The first edition, prepared and published in the difficult war year of 1941, was very limited; for most of us it has been available only through microfilm copies. In view of these circumstances, the appearance of a second edition is especially welcome. And the author has prepared a truly new edition, not just a second printing. He includes much of the solar work carried on between 1941 and the end of 1954.

The book is divided into 12 chapters, the first 10 having the same titles as in 1941, which deal with solar radiation in general, the internal constitution of the sun and sources of solar energy, solar rotation, the photosphere, the line spectrum, sunspots, faculae, the chromosphere, prominences, and the corona. Two new chapters, concerned with solar emission at radio frequencies and with

**Changes in a solar flare and a prominence at the sun's limb are shown in this series of photographs by M. Waldmeier on September 13, 1947. The interval between successive exposures was six minutes. This sequence is Fig. 87 of the book reviewed here, and is reproduced by permission.**



solar-terrestrial relationships, have been added.

Well-drawn, clearly marked diagrams accompany the text throughout the book. Extensive tables summarize certain primary observational data and research findings. These tables should prove valuable to the student who does not have ready access to a solar library.

A number of excellent photographs of the sun are included, such as the fine loop-type prominences of Fig. 97. The reviewers are particularly gratified with two photographs (Figs. 82 and 87) of flares at or near the limb of the sun, which indicate that in certain cases solar flares are elevated phenomena. The latter figure is here reproduced; it shows the changes in a flare and an apparently neighboring prominence in the course of an hour's observation. The fact that the bright feature at the left is a flare, comparable in intensity to flares seen on the disk, would perhaps be more obvious had the scene been photographed without an occulting disk.

As well as being a veritable handbook of solar information, Dr. Waldmeier's book provides an excellent guide to research papers in the literature. In addition to extensive bibliographical references supporting the text, there are tables in which detailed research papers are organized by subject. The subjects so treated range from general matters such as the absolute magnitude of the sun (Table 1) to the details of solar rotation (Table 14) and the Fraunhofer lines in which spectroheliograms have been recorded (Table 49). The bibliographical tables offset in a measure the unfortunate absence of both subject and name indexes.

The author of this book has observed the sun and studied solar data assiduously for many years. College astronomy students and others who read German will find this new text a comprehensive presentation of solar astronomy.

HELEN W. DODSON
E. RUTH HEDEMAN
McMath-Hulbert Observatory

## NEW BOOKS RECEIVED

THE AMERICAN EPHEMERIS AND NAUTICAL ALMANAC FOR THE YEAR 1958, *Nautical Almanac Office*, U. S. Naval Observatory, 1956, *U. S. Government Printing Office*, Washington 25, D. C. 593 pages. $4.00.

The 1958 volume of the *American Ephemeris* does not differ in arrangement from that for 1957. Among its contents are precise ephemerides for the sun, moon, the planets from Mercury through Pluto, and the first four asteroids; there are extensive predictions for eclipses, occultations, and satellites; and much additional material is furnished for astronomers and computers. The physical ephemerides for the moon and planets are indispensable to amateurs who study these objects in detail.

DIE MONDFINSTERNISSE, *Frantisek Link*, 1956, *Akademische Verlagsgesellschaft*, Sternwartenstrasse 8, Leipzig C1, East Germany. 127 pages. DM 15.

"Lunar Eclipses" is a monograph written in German by a well-known Prague astronomer. While dealing with all aspects of eclipses of the moon, the book is devoted mainly to photometric problems. The bibliography contains 192 references.

EDMOND HALLEY 1656-1742, 1956, *British Astronomical Association*, 303 Bath Rd., Hounslow West, Middlesex, England. 39 pages. 5s, paper bound.

The three papers of this Memoir (Vol. 37, No. 3) of the British Astronomical Association, written by Angus Armitage and Colin A. Ronan, are published on the 300th anniversary of the birth of the second Astronomer Royal. Mr. Armitage describes Halley's astronomical heritage, while Mr. Colin discusses the man and his work, then the effect his astronomical achievements had on the future of the science. The appendix is a chronological listing of Halley's life and work, with 104 entries. An example of his versatility is given by the items for the year 1721, rather late in his life:

Resignation as Secretary of the Royal Society.

Erection of the first transit instrument at Greenwich.

Papers on refraction, on determination of planets' positions when close to stars, and on the diving helmet.

More work on the variations of the compass.

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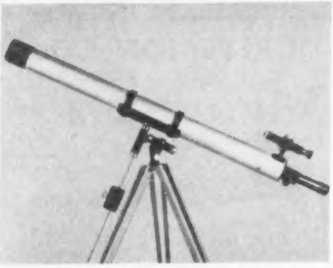

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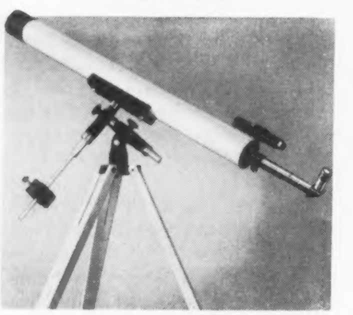

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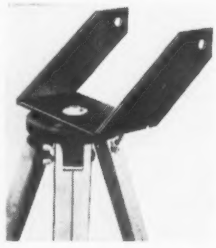

Put your telescope to use as soon as it's finished, by using this mount. Later you can remove the offset yoke and bolt an equatorial mounting of pipe fittings or other parts to the tripod head. Or, if you don't need a portable telescope, buy only the offset yoke to bolt to a post in the ground. Takes tubing up to 7½" outside diameter. This yoke is made of ¼"-thick painted steel plate. The tripod head is machined cast iron, 6½" diameter, gray crinkle. The three sturdy hardwood legs are 32" long.

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Mounted Kellner Eyepiece, Type 3. 2 achromats, F.L. 28-mm., eye relief 22-mm. An extension added, O.D. 1¼", standard for all types of telescopes. Govt. cost $26.50.

**Stock #5223-Y ............ $7.95 ppd.**

## EDSCORP SATELLITE TELESCOPE

**THE STORY:** From the beginning of the visual satellite program, Edmund Scientific Co. was consulted by the Coordinator of Visual Satellite Observations of the Smithsonian Astrophysical Observatory in order to find existing optical instruments or to help in the development of new ones to meet the unique requirements of MOONWATCH. Every effort was to be made to get an instrument with the greatest possible field, which would still have the ability to observe faint objects with only slight magnification. All this was to be provided at a minimum cost. More than thirty different optical arrangements were examined and evaluated by expert advisors to the MOONWATCH program. The optics which we have used have been described in the *Bulletin for Visual Observers of Satellites* as providing the best combination for the purpose.

**OPTICS:** The Satellite Scope has two important optical characteristics: A wide (51-mm.) diameter, low-reflection-coated objective lens. A six-element extremely wide field, coated Erfle eyepiece that, in combination with the objective, gives 5.5 power with a big 12° field and over 7-mm. exit pupil.

**MOUNT:** The mount came in for special attention because of unique requirements of group observing. The center of rotation of the instrument is just below the point where the optical axis is deflected by the front-surface mirror. The mirror is set at 45° to the axis of the telescope barrel and reflects light at exactly 90°. Side brackets and wing nuts permit fast, easy elevation and rigid locking. Rubber eyeguards and the angle of the telescope permit the greatest comfort in long-time viewing. The wide field and our special mount permit the utmost coverage of the possible passage of the satellite without omission of an area of the sky by a string of observers.

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1. Makes a perfect wide-field finder. A special groove on the barrel helps in locating it in the finder mount. Fits our twin-ring finder mount, Stock No. 70,079-Y—$9.95. 2. Use the Erfle eyepiece on your regular astronomical telescope. You will need our adapter, Stock No. 30,171-Y—$3.95, which gives you an O.D. of 1¼". This eyepiece cost the government $56.00! 3. Makes a wonderful comet seeker; see complete asterisms. 4. Makes a fine rich-field telescope; see wide areas of sky with deep penetration.

**Especially Made for Members of MOONWATCH**
**Stock #70,074-Y ............ $49.50 ppd.**

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**Here's An Interesting "Do-It-Yourself" Project**

If you want to build your own Satellite Scope, we can supply the optical parts, or any metal parts from our assembled Satellite Scope. We'll be glad to send you full description of these components together with price information.

**WRITE FOR SATELLITE BULLETIN #40-Y**

**ASTRONOMICAL TELESCOPE TUBING**

| Stock No. | I.D. | O.D. | Lgth. | Description | Price |
|---|---|---|---|---|---|
| 80,038-Y | 4⅞" | 5¼" | 46" | Spiral-wound paper | $2.50 |
| 85,008-Y | 6⅞" | 7⅜" | 60" | Spiral-wound paper | 4.00 |
| 85,011-Y | 2¾" | 3" | 48" | Aluminum | 6.00 |
| 85,012-Y | 3¾" | 4" | 60" | Aluminum | 8.75 |
| 85,013-Y | 4¾" | 5" | 48" | Aluminum | 9.00 |
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All tubing is shipped f.o.b. Barrington, N. J.

# EDMUND SCIENTIFIC CO.

# QUESTAR DATA

**The incomparable Questar is the result of ten years of single-minded devotion to the ideal of creating the finest and most versatile telescope in the world. No lesser time or smaller sum of lavish care could have produced an instrument of such impressive excellence, for in this life nothing much worth while has ever been done in haste.**

**No telescope since Galileo has freed you from the fetters of tradition in so many ways, or earned so many patent awards. None has done so many things so well, or outperformed so many larger instruments.**

**In our limited production of the handmade Questar, we use a variety of ultramodern materials and techniques, which we shall try to describe here. In every smallest part our search has been for the best obtainable, the finest we can buy.**

## OPTICS

PERFORMANCE. **Effective focal length 1077 mm. (42.4"); focal ratio f/12.1; field of view 55 minutes at 40x, 42.5 min. at 80x, 21 min. at 160x. Field flat. Infrared focus identical. No coma, astigmatism, or chromatic aberration, visual or photographic. Theoretically perfect resolution of 1.3 seconds. Questar's resolution at least equals and usually betters the physical limit as defined by Lord Rayleigh on the basis of the Airy disk of a star image.**

FRONT LENS. **Aperture 89 mm. (3.505"), diametral tolerance .0005". Centering absolute. Axial thickness .350" ±.00025". R2 fluoride coated. Precision-annealed glass. Central obstruction 1.07" dia. Cassegrain secondary mirror .800" dia.**

MIRROR. **Perforated, center mounted, 3.8" dia., thinner at periphery, as calculated for minimum flexure. Surface 1/64 wave or better to true spherical, two-hour period of ultra-polish after figuring. Radius tolerance ±.006". Each mirror figured, then vacuum flash coated and tested with full reflectivity. Only after completing performance test is Al-SiO coating applied.**

ERECTING PRISM. **Amici type, 90°, 2 sec. roof angle, coated.**

FINDER MIRROR. **.900" dia. pitch polished, Al-SiO coated.**

AMPLIFYING LENS. **.700" dia. negative achromat, negative f.l. 1.73", coated. Factor approx. 2x.**

EYEPIECES. **40x, 26 mm. 3-lens Koenig 50° field, focusing mount. 80x, 13 mm., 5-lens (2 doublet, 1 single) Erfle, 75° apparent field, extra-long eye relief, focusing mount. Both threaded to adapter tube.**

SUN FILTER. **1.625" dia., .200" thick. Each tested before acceptance for perfect definition uncoated. Multiple-layer coated with pure chromium, front side, with nonselective color transmission 1 in 50,000. Density as recommended by Mr. Cyrus Fernald, Solar Division, AAVSO. Aluminum cell, black linen Synthane threaded disk, screws into lens cell.**

## BARREL

BARREL **of Synthane, Grade XX, fabricated for Questar on mandrel, O.D. ground to tolerance and engine turned. Stabilized after fabrication by controlled process.**

MOON MAP. **Cemented to barrel of De Luxe Model after rolling to perfect tube. High purity aluminum sheet, .016" thick, hand buffed, anodized, dyed deep royal blue; high rejection rate for beauty defects. Accepted sheets etched and white enamel filled.**

**Barrel of Field Model hand covered in genuine Morocco by custom fine bookbinders.**

STAR CHART (DEWCAP). **Composite structure of great strength and durability, similar to barrel, metal armored Synthane, internally black flocked, etched lines lilac enamel filled, 430 stars pale yellow enamel filled. A work of art in its glowing sapphire-plated surface.**

LENS CELL. **Laminated linen Synthane, black, hand turned on engine lathe. Cemented fit to tube.**

LENS RETAINING RING. **Linen Synthane, hand turned. In this Questar assembly no metal touches the front lens, and no mechanical strain distorts its curvatures.**

INTERIOR FINISH. **Sprayed after masking with new alkyd dead black paint with special large-molecule carbon pigment, a remarkable product.**

LIGHT-BAFFLE TUBE. **Has 20 knife-edge internal stops.**

FOCUSING MECHANISM. **Mirror mounted at perforation, on metal thimble, free standing, tapered to periphery. Thimble has 3" bearing length, stainless tube moving along stainless tube, for focus 8 feet to infinity. Conical stainless steel spring loaded, silicone grease lubricated. Focus rod stainless steel 303, 56 T.P.S. Moly lubricated, nylon thrust bearing.**

KNOBS. **Aluminum 24S-T4. Hand turned from solid bar stock on turret lathe, individually handled to preserve beauty of clean-cut metal. Corrosion resistant.**

FINGER-FLICK LEVERS. **302 stainless steel, ground and polished.**

SHAFTS. **302 stainless steel, precision ground.**

FASTENINGS. **Stainless steel, 18-8 chromium-nickel alloy 302. Adjustable screws have slotted heads for screwdriver. Permanent fastening screws are finest procurable. Bristol 302 stainless steel forged spline-head, engine turned, with polished heads. Splined wrench exerts wholly rotary motion. Setscrews, Bristol splined, alloy steel, cup point.**

## MOUNTING

BASE. **Aluminum sand casting, virgin alloy 356-T6 heat treated. Hand turned in toolroom, jig bored and precision reamed to ±.0001" for legs. Hand polished, no paint, highly corrosion-resistant. Bottom flange 7" O.D.**

TURNTABLE. **or lower fork base. Sand casting, same alloy, toolroom turned, jig bored and precision reamed.**

LEGS. **.625" dia. tubing, alloy 61S-T3 centerless ground to ±.0001", anodized. This permits precision push fit. Center leg adjustable for latitudes 32° to 55°, and extension assembly will not come apart.**

BASE HOLE PLUGS, **or car attachment and auxiliary base plate attachment screws. 24S-T4 aluminum staked to shank of 10-32 stainless steel socket-head screws. Neoprene O-ring permits push fit to leg holes.**

BASE COVER PLATE. **bottom. Black Synthane, engine turned and jig bored.**

SYNCHRONOUS DRIVE MOTOR. **115-v. 60-cycle a.c. (50-cycle optional). Reverse rotation optional for Southern Hemisphere. Sealed gear train, sealed-in lubrication, special low-heat winding and anti-hysteresis heat dam. Runs with no perceptible heat. Drive error 10 seconds per hour.**

RIGHT-ASCENSION GEAR. **Bronze, 4" pitch dia. Bearing dia. 4" (driven tube assembly only 10½" long). Assembly rotates on nylon bearing surfaces, 4" dia. Bearing stud ¼" dia.**

SIDE ARMS, INNER FORK BRACKETS, CONTROL BOX **are die castings, corrosion-resistant aluminum alloy 13. Toolroom turned, milled, tapped, jig bored, and precision reamed. Special process aluminum paint, baked, clear enamel coated and again baked, providing a finish impervious to acetone or paint remover. Side arm edges again hand polished after painting.**

FINDER MIRROR CAGE. **Steel, copper-nickel-chrome plated, dull finish. Adjustable mirror platform for collimation, stainless steel spring loaded.**

INNER FORK RING. **Toolroom turned, 24S-T4 aluminum. Jig assembled with brackets and ¼" dia. bearing studs, fastened by screws of 302 stainless steel forged spline-head, engine turned, polished heads.**

ALTITUDE OR DECLINATION CIRCLE. **3 15/16" dia., 302 stainless steel, 360° etched black enamel filled, hand polished both sides and edge, riveted to ring assembly.**

CLAMP. **Threaded stainless steel 302 headed stud, Synthane washer faced both sides, pulls altitude circle against left side arm of fork to clamp in a quarter turn. Two internal splined alloy steel setscrews bear against opposing milled flats in stainless steel stud to secure the knob.**

AZIMUTH OR R.A. CIRCLE. **6" dia. Graduated to four minutes of time, single degrees, over 360° of arc. Aluminum, anodized, deep blue dyed, engraved and white enamel filled. Rotates with fork, may be hand set to become a 6" celestial clock, motor driven with assembly. Slow motion independent of drive and circle.**

SLOW MOTIONS. **Continuous, 360° rotation, safety clutch held. Gearless drive with absolutely no backlash, no lag or play at all. Duplicate drives on both axes. Has been called the smoothest control on any instrument. Consists of three stainless steel disks, micro-rolled expressly for Questar from thicker commercial sheets, free floating, of controlled high-temper alloy 302 against hardened alloy V-pulley pinion. Drive is neutralized without strain when clamp is applied. Ratio 31 to 1. Has tested 32,000 knob turns without visible wear. Permits orientation control to a few seconds of arc.**

## DIMENSIONS

DE LUXE QUESTAR. **Height, upright 14", with barrel horizontal 11", length 11". Weight 6.5 lbs., in case 10.5 lbs. Case 7½" x 7½" x 15".**

FIELD MODEL. **Height 4⅞", length 10¼". Weight 21 oz., in case 46 oz. Case 5¼" x 4¼" x 10¾".**

**Cases of finest British cowhide, handmade in Staffordshire, England. Luggage tan color, full custom lined in old-wine color velvet, leather pouches for accessories. Finest procurable. Rim of Questar's base held in case by adjustable eccentric Synthane disks.**

*De Luxe Questar, $995; Field Model, $495.*

*Easy Payment Plan available. Literature on request.*

**QUESTAR CORPORATION**
**New Hope, Pennsylvania**

# GLEANINGS FOR ATM's

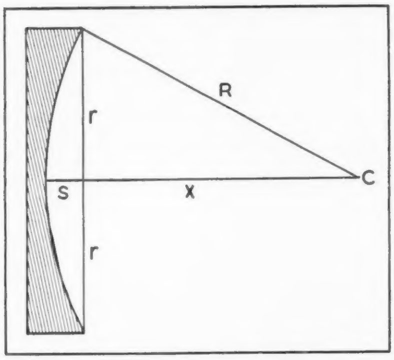
CONDUCTED BY ROBERT E. COX

## When Is an Accurate Sagitta Formula Important?

MOST telescope makers are so familiar with the expression for the sagitta, or depth of curve on a spherical mirror, as being simply $r^2/2R$ that they are likely to forget that it is merely an approximation. We have gotten along with this expression for a long time and have made some very good f/8 paraboloids.

But $r^2/2R$ holds good only when the sagitta is very small in relation to the focal length, as in the case of an f/8 mirror, where the difference between the approximate and accurate values is negligible. When working with shorter focal ratios, however, say f/4, we have found that the radius of curvature inexplicably came out a little longer than anticipated. If a mirror were to be used in a Cassegrainian system, a lot of work was required to shorten the radius to agree with our plans, or possibly we altered the plans to fit the mirror.

In very fast systems, and those combining lenses and mirrors (catadioptric),




**This diagram illustrates some geometrical properties of a spherical concave mirror. In the drawing as well as in the text, R is the radius of curvature, and r is the radius of the mirror itself. The sagitta, or maximum depth of the surface, is represented by S = R − x.**

spherical curves of very short radius are necessary, and when the focal ratio is f/2 or less, the $r^2/2R$ formula begins to break down very seriously. It is the purpose of this article to show that the error in the radius of curvature may become quite significant unless a more precise sagitta formula is used.

In the diagram, the symbols are self-explanatory. From simple geometry,

$$R^2 = x^2 + r^2,$$

or

$$x = \sqrt{R^2 - r^2}.$$

Since **S** is equal to **R** − **x**,

$$S = R - \sqrt{R^2 - r^2}. \quad (1)$$

The right-hand side of this equation is not as simple to evaluate as $r^2/2R$, for it requires extracting a square root, but has the virtue of being exact instead of an approximation. Equation 1 can be rewritten in another way, when expanded by the binomial theorem, to give:

$$S = r^2/2R + r^4/8R^3 + r^6/16R^5 + \ldots \quad (2)$$

From this we see that the familiar approximation is only the first term of a series expansion based on the exact formula which, of course, takes in the whole series. (The second term, $r^4/8R^3$, is the familiar expression for the difference at the edge of a mirror between a sphere and a paraboloid with their centers touching; when expressed in terms of focal length instead of radius, the term becomes $r^4/64F^3$.)

The accompanying table shows what the difference in computed values of the sagitta amounts to, for selected cases of the focal ratio and mirror diameter. When are these differences worth considering? For mirrors of longer focus than f/5.6, the simple formula is within 0.1 per cent of the true sagitta. If your mirror is between f/5.5 and f/3.3, the result of the simple formula should be increased by 0.1 per cent; f/3.2 and f/2.5, 0.2 per cent; f/2.4 and f/2.2, 0.3 per cent. The table shows that for mirrors of f/2

| *Mirror diam.* | *Focal ratio* | *Radius of curvature* | *Sagitta $r^2/2R$* | *Sagitta Eq. (1)* | *Difference* |
|---|---|---|---|---|---|
| 6 | f/8 | 96 | 0.0469 | 0.0469 | 0.0000 |
| 6 | f/6 | 72 | 0.0625 | 0.0625 | 0.0000 |
| 6 | f/4 | 48 | 0.0937 | 0.0938 | 0.0001 |
| 6 | f/2 | 24 | 0.1875 | 0.1882 | 0.0007 |
| 6 | f/1 | 12 | 0.3750 | 0.3810 | 0.0060 |
| 8 | f/6 | 96 | 0.0833 | 0.0833 | 0.0000 |
| 8 | f/4 | 64 | 0.1250 | 0.1251 | 0.0001 |
| 8 | f/2 | 32 | 0.2500 | 0.2510 | 0.0010 |
| 8 | f/1 | 16 | 0.5000 | 0.5081 | 0.0081 |
| 10 | f/4 | 80 | 0.1563 | 0.1564 | 0.0001 |
| 10 | f/2 | 40 | 0.3125 | 0.3137 | 0.0012 |
| 10 | f/1 | 20 | 0.6250 | 0.6351 | 0.0101 |
| 12 | f/4 | 96 | 0.1875 | 0.1877 | 0.0002 |
| 12 | f/2 | 48 | 0.3750 | 0.3765 | 0.0015 |
| 12 | f/1 | 24 | 0.7500 | 0.7621 | 0.0121 |

and shorter the precise formula must be used.

It is important to remember that a very small change in the sagitta can make a large difference in the radius of curvature. The elements of a compound optical system should be made to an accuracy of 0.001″ in focal length if the system is to be really first class, and at any rate to 0.01″. To express the radius of curvature in terms of the sagitta, rewrite Equation 1 as

$$S^2 - 2RS + r^2 = 0,$$

and solve for **R**,

$$R = \frac{S^2 + r^2}{2S}. \qquad (3)$$



This is a very useful formula, particularly for telescope makers who like to pick up surplus lenses and have to find the radius of curvature of a surface from its measured sagitta and the diameter of the lens.

However, to find the radius of a mirror in this way the sagitta must be measured very accurately. A small error in determining the sagitta will produce an error (**R**/**S** − 1) times as large as the deduced radius of curvature. With a 6-inch f/6 mirror, an error of 0.001″ in the sagitta means a 1.1″ difference in the radius of curvature.

The writer has a very fine spherometer that reads to 0.0001″, but it covers only a circle of 4″, and so is not precise enough. I intend to make an even fancier one with a dial depth gauge, but the more exact way of measuring is with a straightedge across the mirror and a vernier depth gauge or a depth micrometer from the straightedge to the center of the mirror.

I use a piece of ground stock 18″ long with a cross section of 1″ by ½″, which was purchased for less than five dollars, and a Brown and Sharpe vernier depth gauge with the edges ground off from the end so as to leave a very shallow curve. The ground stock is straight and parallel within 0.0001″, and the depth gauge was altered very carefully so as not to upset the vernier.

It is evident that if you want to achieve focal lengths precise to 1/100 of an inch, you should abandon the $r^2/2R$ expression for focal ratios shorter than f/6. And even in the longer focal lengths we should be exceptionally careful in measuring the sagitta, even with a straightedge, or we will have heavy going at the polishing stage to shorten the radius of curvature.


ALLAN MACKINTOSH
97 McLoughlin St.
Glen Cove, N. Y.


NOTE: A frequently occurring practical problem is easily solved by an extension of Mr. Mackintosh's analysis. Suppose you are finishing a concave mirror, and measuring its radius of curvature **R** after each spell of fine grinding. If the last measurement shows the radius must still be changed by $\Delta R$, what will the change $\Delta S$ in the sagitta be?

To a very close approximation, this question is answered by the formula $\Delta S = r^2 \Delta R / 2R^2$, where **r** is the radius of the mirror.

Consider a mirror for which $r = 3''$ and $R = 15''$. Then if the measurement of radius of curvature shows it is in error by 0.200″, the sagitta is out by 0.004″. If the radius is too long, then the curve must be deepened by that amount at the center; if it is too short, the 0.004″ must be removed from the edge zone to obtain the correct radius.

R. E. C.

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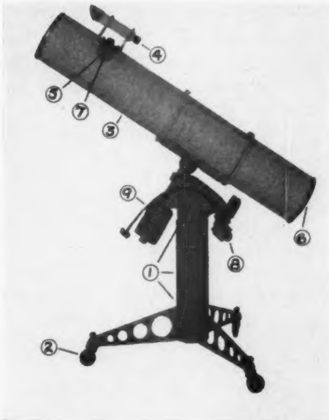


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**All De Luxe models come equipped with 110-volt clock drive, manual flex-line control, setting circles, fully rotating tube, and removable casters. These accessories can be purchased separately for your Standard TRECKERSCOPE model — for ASTRO-FIX, add $42.50 to the De Luxe TRECKERSCOPE price.**

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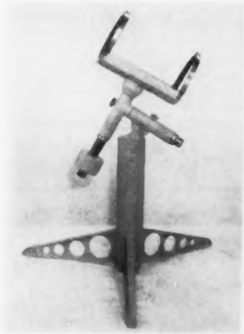
This amazing NEW EQUATORIAL MOUNT is just what the doctor ordered when it comes to "How to mount that homemade telescope you labored so hard to finish." Now — at last — you can purchase a beautifully constructed, highly rigid equatorial mount, COMPLETE, for your own telescope as economically as if you had built it yourself. This terrific new mount is made entirely of metal; all of the moving equatorial parts are polished to work with maximum ease. Legs, head, and counterweight are all removable for easy storing. One of the more important features in this new mount is that the polar axle is extended for ease in attaching a clock drive and/or setting circles, which may be added at any time. The "TRECKER-PATHFINDER" mount also has a beautiful, chip-resistant finish. Taking all of these unusual features into consideration, this is truly one of the best DOLLAR-FOR-DOLLAR values ever offered.



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# OBSERVER'S PAGE

**Universal time is used unless otherwise noted.**

## Another Look at Algol

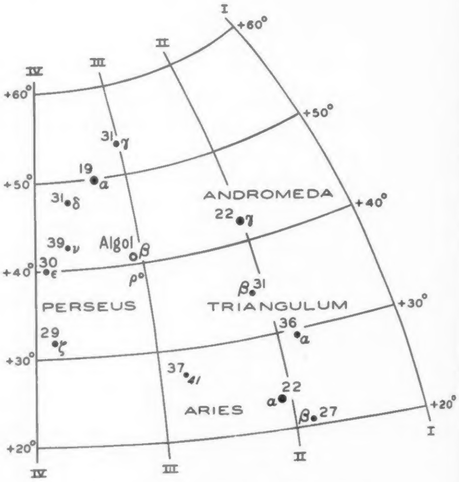
THE variable star Algol (Beta Persei) has a long-term hold on man's imagination. Its striking light changes were first carefully studied in 1782 by an 18-year-old English amateur, John Goodricke. He found that usually Algol was of the 2nd magnitude, but at intervals of 2 days, $20\frac{3}{4}$ hours it faded more than a magnitude and then recovered, the duration of changing brightness lasting about nine hours. Goodricke also suggested what we know today to be the true explanation of this behavior, that Algol has a dark companion which periodically eclipses the brighter star.

About 60 years later, the German astronomer Argelander demonstrated that the period of Algol is itself changing. The chart shows that during the past 180 years Algol minima have taken place as much as $3\frac{1}{2}$ hours ahead of or behind schedule, when the observed times of minimum are compared with predictions based on a constant period.

The steeper the rise of the curve, the longer the period; the rapid fall between 1870 and 1890 indicates an unusually short period during this interval. The minor ripples, especially well-marked in the most recent observations, suggest the complex nature of the variations of Algol's period, for which underlying cycles of 1.87, 32, and 188 years have been surmised. The first of these comes from the 1.87-year orbital motion of the eclipsing pair relative to a third star called Algol C. But the problem is only partly solved, and it seems that the "demon star" still has a few tricks up its sleeve.

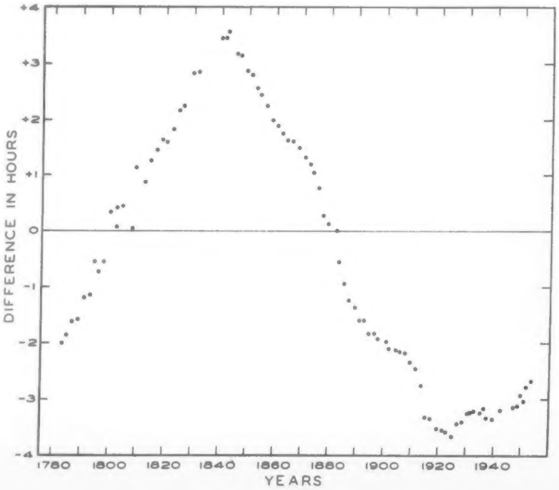
These period changes impart enough uncertainty to the predicted times of minimum to make observational checks quite desirable. Even by naked-eye observations, amateurs can time Algol minima to within about 10 minutes; such an observing project can be both absorbing and useful.

Each month in this magazine all Algol minima are listed, to aid in planning observations, but in the latitudes of the United States only about 35 of them occur above the horizon during the night hours of each year. Moonlight, low altitude of the star, clouds, and the observer's personal engagements cut down this number; however, a persevering amateur usually can time about half a dozen minima in a year.



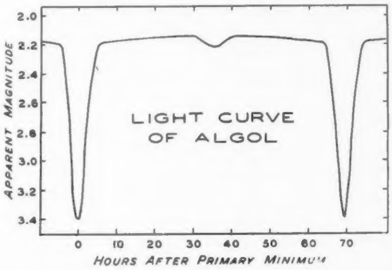

**A finder chart for naked-eye observations of Algol. Visual magnitudes for comparison stars are given, but without decimal points to avoid possible confusion with star symbols.**

The first step in observing Algol is selecting the comparison stars; the accompanying map shows those I have found convenient. The star Rho Persei,




**The deviations of observed times of Algol minima from uniform periodicity are plotted here. Each point is based on from 1 to 66 determinations of the time of minimum. Points before 1932 are from visual data; later ones are from photoelectric observations. The upswing of the curve in recent years shows that the period is again tending to lengthen. Currently the period of Algol is about 2 days, 20 hours, 48 minutes, 57.2 seconds.**

just south of Algol itself, should not be used, as it is also a variable. The brightness of Algol should be estimated to the nearest 0.1 magnitude in terms of the comparison stars, with the time of each estimate recorded to the nearest minute. Algol is normally of magnitude 2.3, so on this chart the stars Gamma Andromedae (2.2) and Alpha Arietis (2.2) are a tenth of a magnitude brighter, not counting color differences. At minimum, Algol is about magnitude 3.5, not quite as faint as Alpha Trianguli and 41 Arietis. This method of estimating the magnitude of a




**A light curve of Algol, based on photoelectric observations.**

variable to the nearest tenth is used by the American Association of Variable Star Observers for long-period variables.

Certain observing precautions are necessary. Poor sky transparency or a low altitude of Algol can cause large errors. It is very important to avoid bias—try to keep each observation independent of the ones before, and do not be influenced by preconceived ideas of what the variable ought to be doing, or by a recollection of the predicted time of minimum. (The prediction may be considerably in error!) If observing conditions permit, estimate the brightness of Algol at intervals of roughly 10 or 15 minutes from about two or three hours before the predicted time of minimum until two or three hours after.

Several techniques can be used to derive the time of minimum from a series of observations made during a single night. The one described here combines ease and accuracy and is in widespread use. First, make a large-scale plot of your observed magnitudes against the time in hours and minutes. A convenient choice of scales is to have 0.1 magnitude correspond to about half an hour.

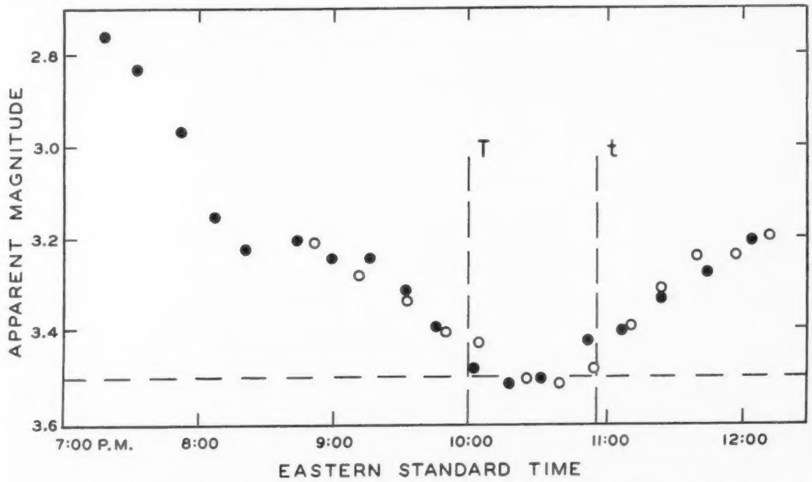
This graph will have a roughly V-shaped array of points. Where does the minimum come? Copy the plotted points on tracing paper, and also one of the co-ordinate lines parallel to the time axis, say the line for magnitude 3.5. Also transfer to the tracing paper some arbitrarily chosen time line, **T**, near the minimum of the star's light.

Now turn the tracing paper over, right for left, so that you are superimposing on the original plot a mirror image of itself. Keep the two horizontal lines for magnitude 3.5 in coincidence, and slide the tracing paper to the right and left until best agreement is obtained between the points underneath and those on the tracing. Together they should make a smooth series—emphasizing the V shape. When this is achieved, read off the time abscissa, **t**, on which the time line on the tracing paper now falls. The time of minimum is the average of **T** and **t**.

We illustrate this process with the series of observations listed here, made by Joseph Ashbrook on November 5-6, 1956. Each observation is the average of three

OBSERVATIONS OF ALGOL
November 5-6, 1956

| *Time* EST | *Magnitude* (Visual) | *Time* EST | *Magnitude* (Visual) |
|---|---|---|---|
| 7:19 p.m. | 2.76 | 9:46 p.m. | 3.39 |
| 7:34 | 2.83 | 10:02 | 3.48 |
| 7:53 | 2.97 | 10:18 | 3.51 |
| 8:08 | 3.15 | 10:32 | 3.50 |
| 8:22 | 3.22 | 10:53 | 3.42 |
| 8:45 | 3.20 | 11:08 | 3.40 |
| 9:00 | 3.24 | 11:25 | 3.33 |
| 9:17 | 3.24 | 11:45 | 3.27 |
| 9:32 | 3.31 | 12:05 a.m. | 3.20 |




**The solid dots represent the November 5-6 observations listed above, while the open circles are the same points on tracing paper, inverted and shifted to achieve the best fit.**

HELIOCENTRIC CORRECTION FOR ALGOL

| *From* | *To* | *Minutes* | *From* | *To* | *Minutes* | *From* | *To* | *Minutes* |
|---|---|---|---|---|---|---|---|---|
| Dec. 29— | Jan. 2 | +5 | Mar. 31— | Apr. 9 | −6 | Aug. 21— | Aug. 28 | +1 |
| Jan. 3— | Jan. 16 | +4 | Apr. 10— | Apr. 29 | −7 | Aug. 29— | Sept. 5 | +2 |
| Jan. 17— | Jan. 24 | +3 | Apr. 30— | May 29 | −8 | Sept. 6— | Sept. 14 | +3 |
| Jan. 25— | Feb. 1 | +2 | May 30— | June 18 | −7 | Sept. 15— | Sept. 22 | +4 |
| Feb. 2— | Feb. 8 | +1 | June 19— | July 1 | −6 | Sept. 23— | Oct. 3 | +5 |
| Feb. 9— | Feb. 16 | 0 | July 2— | July 11 | −5 | Oct. 4— | Oct. 15 | +6 |
| Feb. 17— | Feb. 23 | −1 | July 12— | July 20 | −4 | Oct. 16— | Nov. 5 | +7 |
| Feb. 24— | Mar. 3 | −2 | July 21— | July 28 | −3 | Nov. 6— | Nov. 25 | +8 |
| Mar. 4— | Mar. 11 | −3 | July 29— | Aug. 5 | −2 | Nov. 26— | Dec. 16 | +7 |
| Mar. 12— | Mar. 20 | −4 | Aug. 6— | Aug. 12 | −1 | Dec. 17— | Dec. 28 | +6 |
| Mar. 21— | Mar. 30 | −5 | Aug. 13— | Aug. 20 | 0 | Dec. 29— | Jan. 2 | +5 |

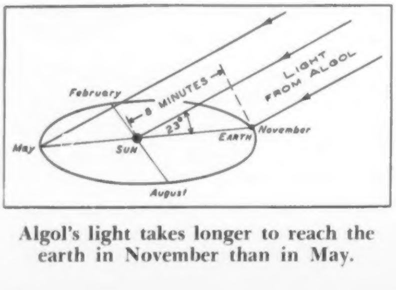
The values listed are to be applied with the signs indicated to observed (geocentric) times to obtain heliocentric times.

or more independent estimates (using different pairs of comparison stars), and therefore the magnitudes are given to two decimal places. On the plot of these observations, the time line **T** was arbitrarily placed at 10:00 p.m. Eastern standard time. When the tracing paper was inverted, the best fit between the two sets of points was when the time line lay on $t$ = 10:56 p.m. Thus, the minimum occurred at the mean of these times, 10:28 p.m. This corresponds to 3:28 Universal time on November 6th, whereas the *Sky and Telescope* prediction was for 3:20 UT, eight minutes earlier. The difference is, however, less than the uncertainty in the observed time, which is about ±10 minutes.

In technical astronomical literature all times of minima of eclipsing variables are given as heliocentric, that is, corrected for the effect of the orbital motion of the earth around the sun. It is useful to be able to correct our geocentric Algol minima for this difference, which can be easily understood with the aid of the diagram. Light takes about 1,000 seconds or nearly 17 minutes to cross the earth's orbit. It is evident that the earth is closer to the star when it is at opposition to the sun, in November, and farther when the star is on the other side.

Therefore, an Algol minimum in November will be timed eight minutes too early, and one in May late by eight minutes. To free our observations from this effect of the travel time of light, which has nothing to do with the star itself, we add the heliocentric correction given in the table. For example, correcting the November 5-6 observation by +8 minutes gives the heliocentric time of that minimum as 3:36 UT.

Finally, we may wish to express the observed heliocentric time of minimum in terms of Julian day numbers, a conversion easily made with the tables in the *American Ephemeris*. The "Calendar" section in the front of the *Ephemeris* tells us that 0:00 UT on November 6, 1956, was Julian day 2,435,783.5. The interval of 3 hours 36 minutes is 0.150 day, according to a simple calculation or Table XII in the back of the *Ephemeris*. Adding this, we find that the heliocentric minimum was at JD 2,435,783.650.




**Algol's light takes longer to reach the earth in November than in May.**

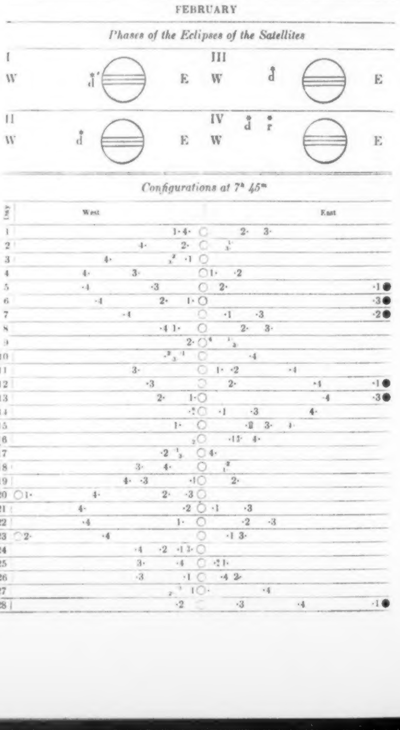
There is a broad field open to amateurs in the timing of minima of eclipsing variables. We have outlined the general procedures to follow, but the tracing-paper method should not be used for the unusual eclipsing systems that have asymmetrical light curves. Furthermore, each star, depending on its position in the sky, needs different heliocentric corrections.

JEREMY H. KNOWLES
196-04 Woodhull Ave.
Hollis 23, N. Y.

## JUPITER'S SATELLITES

The configurations of Jupiter's four bright moons are shown below, as seen in an astronomical or inverting telescope, with north at the bottom and east at the right. In the upper part, $d$ is the point of disappearance of the satellite in Jupiter's shadow; $r$ is the point of reappearance.

In the lower section, the moons have the positions shown for the Universal time given. The motion of each satellite is from the dot toward the number designating it. Transits over Jupiter's disk are shown by open circles at the left, eclipses and occultations by black disks at the right. The chart is from the *American Ephemeris and Nautical Almanac.*



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## VARIABLE STAR MAXIMA

February 1, R Aurigae, 050953, 7.8; 5, R Octantis, 055**686**, 7.9; 8, RU Sagittarii, 1951**42**, 7.2; 12, R Trianguli, 023133, 6.3; 23, T Aquarii, 2044**05**, 7.9.

March 2, T Centauri, 1336**33**, 6.1; 2, X Monocerotis, 065**208**, 7.6; 2, Z Ursae Majoris, 115158, 6.6; 3, T Herculis, 180531, 8.0; 5, RR Scorpii, 1650**30**, 6.0; 5, T Normae, 1536**54**, 7.4.

These predictions of variable star maxima are by the AAVSO. Only stars are included whose mean maximum magnitudes are brighter than magnitude 8.0. Some, but not all of them, are nearly as bright as maximum two or three weeks before and after the dates for maximum. The data given include, in order, the day of the month near which the maximum should occur, the star name, the star designation number, which gives the rough right ascension (first four figures) and declination (bold face if southern), and the predicted magnitude.

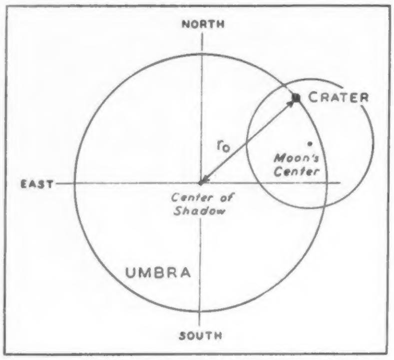


## SIZE OF THE EARTH'S SHADOW DURING THE NOVEMBER LUNAR ECLIPSE

DURING the total eclipse of the moon on November 17-18, 1956, several amateurs carefully timed when individual craters entered and emerged from the umbral shadow of the earth. These observations can be used to determine the apparent radius of the umbra, which is always larger than predicted from the geometry of the eclipse.

This enlargement differs in amount from eclipse to eclipse, and there has been controversy as to whether or not the changes are related to the sunspot cycle. The Czech astronomer, F. Link, who believes the enlargement results from an absorbing layer in the earth's upper atmosphere, has stressed the value of amateur observations of crater contact times.

The diagram shows how such an observation is evaluated. Each observer has recorded the time when a lunar crater is on the edge of the umbra. For this time, the position of the moon's center with respect to the center of the shadow may be computed from data in the *American Ephemeris*. The co-ordinates of the crater with respect to the moon's center can be calculated, taking libration into account. Finally, from these numbers we obtain the observed radius of the umbra. For these reductions I used the formulas published in 1940 by the Russian astronomer S. Kosik (*Bulletin* No. 13 of the Tashkent Observatory).




**The earth's umbra at a lunar eclipse.**

In all, 42 contact times were observed, apart from some very discordant cases which may be affected by errors of record or crater misidentifications. In the accompanying table, each observed time is followed by the resulting value of the umbral radius, expressed as a fraction of the earth's equatorial radius. The last column gives the difference between the observed and computed radii ($r_o - r_c$) of the umbra.

The average of all 42 observed values of $r_o - r_c$ is 0.0156 earth radius; dividing by $r_c$ gives 0.0215 as the enlargement of the umbra, with a mean error of ±0.0012. In other words, the umbra appeared 2.15 per cent larger than calculated, according to this set of observations. From the 23 eclipses of 1889 to 1938 that Dr. Link analyzed, he obtained the mean value of 2.5 per cent.

JOSEPH ASHBROOK

ENTRANCE INTO UMBRA

| *Crater* | *Obs'r.* | *UT* | *Observed Rad. ($r_o$)* | *Diff. ($r_o - r_c$)* |
|---|---|---|---|---|
| Riccioli | B | 5:05.6 | 0.749 | +0.023 |
| Grimaldi | E | 5:06.6 | .744 | .018 |
| Grimaldi | T | 5:08.0 | .735 | .009 |
| Schickard | F | 5:07.6 | .756 | .030 |
| Kepler | K | 5:21.2 | .738 | .012 |
| Tycho | E | 5:21.9 | .744 | .018 |
| Tycho | T | 5:22.7 | .738 | .012 |
| Tycho | K | 5:23.0 | .734 | .008 |
| Tycho | W | 5:23.0 | .734 | .008 |
| Aristarchus | R | 5:22.3 | .758 | .032 |
| Aristarchus | T | 5:24.4 | .742 | .016 |
| Aristarchus | K | 5:25.0 | .738 | .012 |
| Aristarchus | F | 5:25.2 | .736 | .010 |
| Copernicus | E | 5:28.0 | .750 | .024 |
| Copernicus | K | 5:28.5 | .746 | .020 |
| Copernicus | B | 5:28.9 | .742 | .016 |
| Copernicus | T | 5:29.6 | .737 | .011 |
| Copernicus | F | 5:29.8 | .735 | .009 |
| Pytheas | F | 5:31.1 | .735 | .009 |
| Timocharis | F | 5:33.6 | .743 | .017 |
| Archimedes | W | 5:43.4 | .742 | .016 |
| Archimedes | M | 5:43.6 | .740 | .014 |
| Plato | E | 5:49.6 | .744 | .019 |
| Plato | W | 5:50.6 | .737 | .012 |
| Plato | T | 5:50.8 | .736 | .011 |
| Posidonius | T | 5:57.4 | .741 | .015 |
| Proclus | F | 6:00.0 | .736 | .010 |
| Picard | T | 6:00.6 | .741 | .015 |
| Picard | F | 6:00.9 | .739 | .013 |
| Cleomedes | T | 6:02.5 | 0.747 | +0.021 |

EXIT FROM UMBRA

| *Crater* | *Obs'r.* | *UT* | *Observed Rad. ($r_o$)* | *Diff. ($r_o - r_c$)* |
|---|---|---|---|---|
| Aristarchus | K | 7:36.1 | 0.734 | +0.009 |
| Aristarchus | T | 7:36.5 | .737 | .012 |
| Kepler | K | 7:42.8 | .740 | .015 |
| Kepler | T | 7:43.3 | .744 | .019 |
| Plato | T | 7:47.5 | .739 | .015 |
| Schickard | K | 7:48.2 | .742 | .016 |
| Copernicus | T | 7:51.6 | .739 | .014 |
| Copernicus | K | 7:51.8 | .740 | .015 |
| Tycho | K | 8:01.8 | .740 | .014 |
| Tycho | T | 8:02.3 | .744 | .018 |
| Menelaus | T | 8:09.2 | .744 | .019 |
| Posidonius | T | 8:10.5 | 0.753 | +0.028 |

KEY TO OBSERVERS

*B*, S. O'Byrne, 6-inch reflector, 60x, Webster Groves, Mo.; *E*, E. Edwards, 2½-inch refractor, Manhattan Beach, Calif.; *F*, M. Francis, 4-inch reflector, 65x, and M. Wells, 6-inch reflector, Bellwood, Ill.; *K*, F. Kosdon, 10-inch reflector, Buttonwillow, Calif.; *M*, D. Megginson, 6-inch reflector, 80x, Webster Groves, Mo.; *R*, J. Ross, 6-inch reflector, 60x, Webster Groves, Mo.; *T*, K. Thomson, G. Berryhill, and T. Phythian, 8-inch reflector, Pasadena, Texas; *W*, Mrs. W. Fallert, 3-inch refractor, 63x, Webster Groves, Mo.

## MOON PHASES AND DISTANCE

| | |
|---|---|
| First quarter | February 7, 23:23 |
| Full moon | February 14, 16:38 |
| Last quarter | February 21, 12:18 |
| New moon | March 1, 16:12 |

| | February | Distance | Diameter |
|---|---|---|---|
| Perigee | 14, 11ʰ | 221,500 mi. | 33′ 31″ |
| Apogee | 27, 15ʰ | 252,600 mi. | 29′ 23″ |
| | March | | |
| Perigee | 14, 22ʰ | 223,100 mi. | 33′ 17″ |

## OCCULTATION PREDICTIONS

February 5-6 **MARS** 0.9, 2:12.4 +14-14.8, 7, Im: **H** 21:25.2 . 132; **I** 21:30.9 −0.9 +1.5 91. Em: **H** 21:55.9 179; **I** 22:39.7 −0.8 +2.4 225.

February 9-10 **Chi² Orionis** 4.7, 6:01.4 +20-08.5, 11, Im: **A** 22:59.8 −1.4 +0.9 90; **B** 23:01.9 −1.2 +1.4 80; **C** 22:50.6 −1.4 +0.7 99; **D** 22:52.7 −1.1 +1.3 82.

February 20-21 **Omega¹ Scorpii** 4.1, 16:04.3 −20-33.3, 22, Im: **F** 12:29.0 −2.9 +0.9 69; **H** 11:38.5 −1.9 +1.2 80; **I** 11:57.4 −2.1 +2.5 47. Em: **H** 12:56.6 −1.8 −0.7 308; **I** 12:41.8 −0.7 −1.0 337.

February 20-21 **Omega² Scorpii** 4.6, 16:04.9 −20-45.2, 22, Em: **H** 13:31.0 −2.4 +0.2 270; **I** 13:26.1 −1.5 0.0 291.

For stations in the United States and Canada, usually for stars of magnitude 5.0 or brighter, data from the *American Ephemeris* and the *British Nautical Almanac* are given here, as follows: evening-morning date, star name, magnitude, right ascension in hours and minutes, declination in degrees and minutes, moon's age in days, immersion or emersion; standard station designation, UT, **a** and **b** quantities in minutes, position angle on the moon's limb; the same data for each standard station westward.

The **a** and **b** quantities tabulated in each case are variations of standard-station predicted times per degree of longitude and of latitude, respectively, enabling computation of fairly accurate times for one's local station (long. **Lo**, lat. **L**) within 200 or 300 miles of a standard station (long. **LoS**, lat. **LS**). Multiply **a** by the difference in longitude (**LO** − **LoS**), and multiply **b** by the difference in latitude (**L** − **LS**), with due regard to arithmetic signs, and add both results to (or subtract from, as the case may be) the standard-station predicted time to obtain time at the local station. Then convert the Universal time to your standard time.

Longitudes and latitudes of standard stations are:

| | | | | | |
|---|---|---|---|---|---|
| **A** | +72°.5, | +42°.5 | **E** | +91°.0, | +40°.0 |
| **B** | +73°.6, | +45°.5 | **F** | +98°.0, | +31°.0 |
| **C** | +77°.1, | +38°.9 | **G** | Discontinued | |
| **D** | +79°.4, | +43°.7 | **H** | +120°.0, | +36°.0 |
| | | | **I** | +123°.1, | +49°.5 |

## PREDICTIONS OF BRIGHT MINOR PLANET POSITIONS

**Aethra,** 132, 9.4. February 11, 11:25.7 −48-07; 21, 11:23.6 −50-55. March 3, 11:18.3 −52-35; 13, 11:11.4 −53-00; 23, 11:05.3 −52-07. April 2, 11:02.3 −50-04.

**Eunomia,** 15, 9.3. February 11, 11:11.3 −8-39; 21, 11:03.1 −8-32. March 3, 10:54.1 −8-08; 13, 10:44.9 −7-31; 23, 10:36.7 −6-45. April 2, 10:30.1 −5-56.

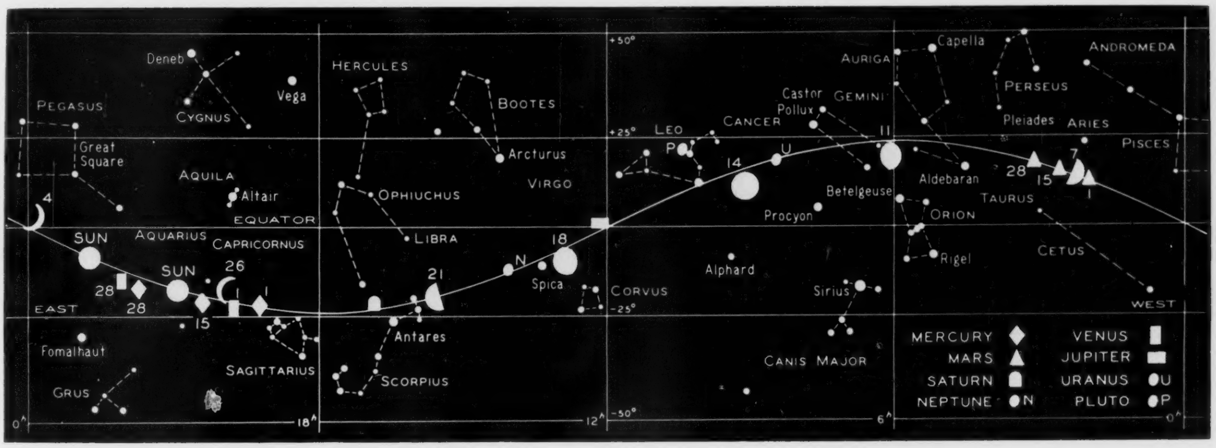
**Parthenope,** 11, 9.8. February 11, 11:50.4 +5-44; 21, 11:44.5 +6-46. March 3, 11:36.9 +7-56; 13, 11:28.1 +9-08; 23, 11:19.3 +10-13. April 2, 11:11.5 +11-05.

After the asteroid's name are its number and the magnitude expected at opposition. At 10-day intervals are given its right ascension and declination (1950.0) for $0^h$ Universal time. In each case the motion of the asteroid is retrograde. Data are supplied by the IAU Minor Planet Center at the University of Cincinnati Observatory.

## SUNSPOT NUMBERS

**November 1,** 157; **2,** 175; **3,** 187; **4,** 198; **5,** 220; **6,** 274; **7,** 321; **8,** 295; **9,** 242; **10,** 236; **11,** 256; **12,** 262; **13,** 205; **14,** 205; **15,** 246; **16,** 236; **17,** 231; **18,** 180; **19,** 178; **20,** 180; **21,** 183; **22,** 154; **23,** 165; **24,** 175; **25,** 190; **26,** 130; **27,** 122; **28,** 115; **29,** 164; **30,** 198. Mean for November: 202.7.

Above is given the date, followed by the Zurich number. These are observed mean relative sunspot numbers from Zurich Observatory and its stations in Locarno and Arosa. The American numbers will become available later.




### THE SUN, MOON, AND PLANETS THIS MONTH

**The sun, on the ecliptic, is shown for the beginning and end of the month. The moon's symbols give its phase roughly, with the date marked alongside. Each planet is located for the middle of the month or for other dates shown.**

**Mercury** reaches greatest elongation on February 2nd, 25° 19′ west of the sun, when it rises $1\frac{1}{2}$ hours before sunrise. This planet now appears at magnitude +0.1, and may be followed in the morning sky until the middle of the month.

**Venus.** Before it moves too close to the sun, Venus may be observed during the first week of February, rising only about 45 minutes ahead of the sun. Its magnitude will be −3.3.

**Mars** traverses Aries in February, and appears as a reddish 1st-magnitude object setting shortly before midnight. Mars will be occulted by the moon on the afternoon of the 6th, an event visible in daylight in moderate-sized telescopes from Pacific Coast states.

**Jupiter** is a prominent evening object; late in the month it rises as twilight ends. The giant planet is now retrograding in western Virgo. It increases during February both in apparent size and brightness—to an equatorial diameter of 42″.8 and magnitude −1.9 on the 15th of the month, making it a fine object for small telescopes.

**Saturn** appears in the southeast during the early morning hours, about 6° northeast of Antares and at magnitude +0.7. The ringed planet continues to move slowly eastward, with the northern face of the rings inclined by 26°.2 to our line of sight in mid-February. On the morning of the 22nd the moon will be very close to Saturn, and an occultation will be visible in parts of the tropics and the Southern Hemisphere.

**Uranus** may be observed with slight optical aid throughout the night, as opposition occurred last month. This 6th-magnitude planet is in retrograde or westward motion in Cancer, about 3° west of the Praesepe star cluster.

**Neptune** begins to retrograde on February 3rd, preceding its opposition in April. Located in eastern Virgo, at R. A. $14^h\ 03^m.5$, Dec. −10° 40′ (1950) on the 15th, this 8th-magnitude object may be viewed after midnight.

**Pluto** will reach opposition to the sun on the 18th, in Leo at $10^h\ 22^m.0$, + 22° 27′ (1950). This 15th-magnitude planet will be 33.6 astronomical units distant from the earth at that time. E. O.

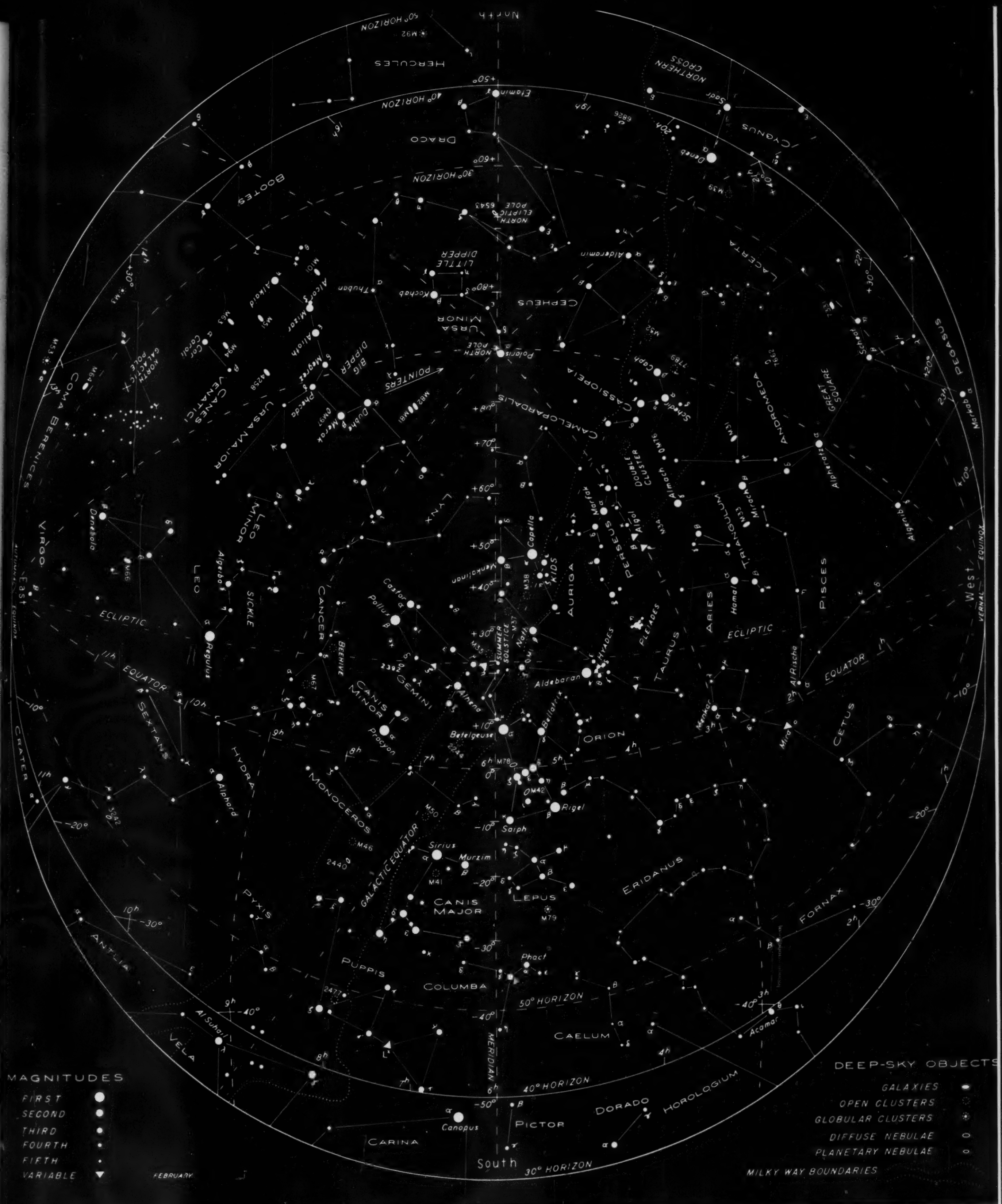
### MINIMA OF ALGOL

February 3, 0:42; 5, 21:31; 8, 18:21; 11, 15:10; 14, 12:00; 17, 8:49; 20, 5:38; 23, 2:28; 25, 23:17; 28, 20:06. March 3, 16:56; 6, 13:45.

These minima predictions for Algol are based on the formula in the 1953 *International Supplement* of the Krakow Observatory. The times given are geocentric; they can be compared directly with observed times of least brightness.

### UNIVERSAL TIME (UT)

TIMES used on the Observer's Page are Greenwich civil or Universal time, unless otherwise noted. This is 24-hour time, from midnight to midnight; times greater than 12:00 are p.m. Subtract the following hours to convert to standard times in the United States: EST, 5; CST, 6; MST, 7; PST, 8. If necessary, add 24 hours to the UT before subtracting, in which case the result is your standard time on the day preceding the Greenwich date shown.




## STARS FOR FEBRUARY

The sky as seen from latitudes 30° to 50° north, at 9 p.m. and 8 p.m., local time, on the 5th and 21st of February, respectively; also, at 7 p.m. and 6 p.m. on March 7th and 23rd. For other dates, add or subtract ½ hour per week.

When facing north, hold "North" at the bottom; turn the chart accordingly for other directions. The equator, ecliptic, galactic equator, and meridian are dashed curves, as are hour circles three hours east and west of the meridian.

# AIRSPACED OBJECTIVES

## MOUNTED IN ALUMINUM CELLS f/15

We offer the lowest priced, hand-corrected, precision, American-made astronomical objective, *mounted in a black anodized aluminum cell.* Our reputation has been established over the years as the most reliable source of high quality astronomical lenses.

**"Those in the know" BUY FROM US BECAUSE:**

Each lens is thoroughly tested by us and is guaranteed to resolve two seconds of arc or better. They are corrected for the C and F lines (secondary chromatic aberration). The zonal spherical aberration and the chromatic variation of spherical aberration are negligible. The cell is machined to close tolerances so that it will fit directly over our standard aluminum tubing, eliminating any mounting problems.

3¼" diam., 48" f.l. (uncoated).. **$28.00**
Same as above with coating..... **$32.00**
4⅛" diam., 62" f.l. (uncoated).. **$60.00**
Same as above with coating..... **$69.00**

We can supply ALUMINUM TUBING for the above lenses.

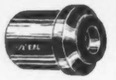
## "BIG" ACHROMATIC TELESCOPE OBJECTIVES

We have the largest selection of diameters and focal lengths in the United States available for immediate delivery. These are perfect magnesium-fluoride coated and cemented Gov't. surplus lenses made of finest crown and flint optical glass. Not mounted. Fully corrected. Tremendous resolving power. They can readily be used with eyepieces of only ¼" focal length, thereby producing high powers. Guaranteed well suited for astronomical telescopes, spotting scopes, and other instruments. Gov't. cost up to $100.

| Diameter | Focal Length | Each | Diameter | Focal Length | Each |
|---|---|---|---|---|---|
| 54 mm (2⅛") | 254 mm (10")....... | $12.50 | 83 mm (3¼") | 660 mm (26")....... | $28.00 |
| 54 mm (2⅛") | 300 mm (11.8")..... | 12.50 | 83 mm (3¼") | 711 mm (28")....... | 28.00 |
| 54 mm (2⅛") | 330 mm (13")....... | 12.50 | 83 mm (3¼") | 762 mm (30")....... | 28.00 |
| 54 mm (2⅛") | 390 mm (15.4")..... | 9.75 | 83 mm (3¼") | 876 mm (34½").... | 28.00 |
| 54 mm (2⅛") | 508 mm (20")....... | 12.50 | 83 mm (3¼") | 1016 mm (40")....... | 30.00 |
| 54 mm (2⅛") | 600 mm (23½").... | 12.50 | 102 mm (4") | 876 mm (34½").... | 60.00 |
| 54 mm (2⅛") | 762 mm (30")....... | 12.50 | 108 mm (4¼") | 914 mm (36")....... | 60.00 |
| 54 mm (2⅛") | 1016 mm (40")....... | 12.50 | 110 mm (4⅜")* | 1069 mm (42$\frac{1}{16}$").... | 60.00 |
| 54 mm (2⅛") | 1270 mm (50")....... | 12.50 | 110 mm (4⅜") | 1069 mm (42$\frac{1}{16}$").... | 67.00 |
| 78 mm (3$\frac{1}{16}$") | 381 mm (15")....... | 21.00 | 128 mm (5$\frac{1}{16}$")* | 628 mm (24¾").... | 75.00 |
| 80 mm (3⅛") | 495 mm (19½").... | 28.00 | 128 mm (5$\frac{1}{16}$") | 628 mm (24¾").... | 85.00 |
| 81 mm (3$\frac{3}{16}$") | 622 mm (24½").... | 22.50 | *Not coated | | |

We can supply ALUMINUM TUBING for the above lenses.

## MOUNTED EYEPIECES



The buy of a lifetime at a great saving. Perfect war-surplus lenses set in black anodized standard aluminum 1¼" O.D. mounts.

| F.L. | TYPE | PRICE |
|---|---|---|
| 12.5 mm (½") | Symmetrical................. | $ 6.00 |
| 16 mm (⅝") | Erfle (wide angle)......... | 12.50 |
| 16 mm (⅝") | Triplet...................... | 12.50 |
| 18 mm (¾") | Symmetrical................. | 6.00 |
| 22 mm ($\frac{27}{32}$") | Kellner....................... | 6.00 |
| 32 mm (1¼") | Orthoscopic.................. | 12.50 |
| 35 mm (1⅜") | Symmetrical................. | 8.00 |
| 55 mm (2$\frac{3}{16}$") | Kellner....................... | 6.00 |

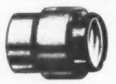
**COATED** 75 cents extra.

## ASTRONOMICAL MIRRORS

These mirrors are of the highest quality, polished to ¼-wave accuracy. They are aluminized, and have a silicon monoxide protective coating. You will be pleased with their performance.

| | Diam. | F.L. | Postpaid |
|---|---|---|---|
| Plate Glass | 3$\frac{3}{16}$" | 42" | $ 9.75 |
| Pyrex | 4¼" | 45" | $13.50 |
| Pyrex | 6" | 60" | $25.00 |

## AN ECONOMICAL EYEPIECE



This mounted eyepiece has two magnesium-fluoride coated lenses 29 mm in diameter. It is designed to give good eye relief. It has an effective focal length of 1¼" (8x).

The eyepiece cell fits a 1¼" tube........ **$4.50**

## Aluminum Telescope Tubing

| O.D. | I.D. | Price Per Ft. |
|---|---|---|
| 2¼" | 2⅛" | $1.20 |
| 3⅜" | 3¼" | 1.75 |
| 4½" | 4⅜" | 2.75 |
| 5" | 4⅞" | 2.75 |

All tubing is shipped POSTPAID.

## Focusing Eyepiece Mounts Rack & Pinion Type

The aluminum body casting is finished in black crackle paint and is machined to fit all our aluminum tubing. Has a chrome-plated brass focusing tube, which accommodates standard 1¼" eyepieces.

| | | |
|---|---|---|
| For 2⅛" I.D. Tubing | Postpaid | $12.95 |
| For 3¼" I.D. Tubing | " | 12.95 |
| For 4⅜" I.D. Tubing | " | 12.95 |

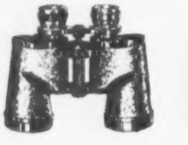
Reflector type for all size tubing.

Complete with diagonal holder....... **$ 9.95**

## Aluminum Lens Cells Black Anodized

| Cell for Lenses | Cell Fits Tubing | Price |
|---|---|---|
| 54 mm Diam. | 2⅛" I.D. | $ 3.50 |
| 78 mm " | 3¼" " | 6.50 |
| 81 mm " | 3¼" " | 6.50 |
| 83 mm " | 3¼" " | 6.50 |
| 110 mm " | 4⅜" " | 10.50 |

## COATED BINOCULARS



American Type

Zeiss Type

Beautiful imported binoculars, precision made, at a low, low price. Above we have pictured the two most popular types. The American Type offers a superior one-piece frame and a clean design, pleasing to the eye. Complete with carrying case and straps. **Price plus 10% Federal tax.**

| SIZE | TYPE | C. FOCUS | IND. FOCUS |
|---|---|---|---|
| 6 x 15 | OPERA | — | $12.75 |
| 6 x 30 | ZEISS | $18.75 | 16.75 |
| 7 x 35 | ZEISS | 21.25 | 19.25 |
| 7 x 35 | AMERICAN | 23.50 | — |
| 7 x 35 | AMERICAN WIDE ANGLE 10° | 37.50 | — |
| 7 x 50 | ZEISS | 24.95 | 22.50 |
| 7 x 50 | AMERICAN | 32.50 | — |
| 8 x 30 | ZEISS | 21.00 | 18.25 |
| 10 x 50 | ZEISS | 30.75 | 28.50 |
| 20 x 50 | ZEISS | 41.50 | 39.50 |

## MONOCULARS

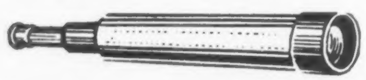
Brand new, coated optics, complete with pigskin case and neck straps.

| | Price | | Price |
|---|---|---|---|
| 6 x 30 | $10.00 | 7 x 50 | $15.00 |
| 8 x 30 | 11.25 | 16 x 50 | 17.50 |
| 7 x 35 | 12.50 | 20 x 50 | 20.00 |

**"MILLIONS" of Lenses, etc. Free Catalogue**

We pay the POSTAGE — C.O.D.'s you pay postage. Satisfaction guaranteed or money refunded if merchandise returned within 30 days.

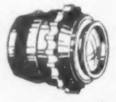
## "GIANT" 3" TELESCOPE



**40 power** Special Price **$57.50**

Never before has anything like this been offered at so low a price. Here is another example of American ingenuity. Big 3" diameter achromatic coated objective which will give needle-sharp crystal-clear images. Focusing is a delight with the micrometer spiral focusing drawtube. Light-weight aluminum construction throughout, black crackle finish, length open 22 inches, closed 17 inches. This telescope gives an upright image—it is WONDERFUL for astronomy, SUPERB for long distances, EXCELLENT as a spotting scope.

## "GIANT" EYEPIECE



**WIDE ANGLE ERFLE** (68° Field) **EYEPIECE.** Brand new coated 1¼" E.F.L. Focusing mount. 3 perfect achromats, 1$\frac{13}{16}$" aperture. **$12.50**

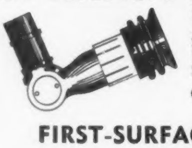
**WIDE ANGLE ERFLE** 1½" E.F.L. Brand new; contains Eastman Kodak's rare-earth glasses; aperture 2"; focusing mounts; 65° field.. **$18.50**

1¼" **Diam. Adapter** for above eyepieces. **$3.95**

**LENS CLEANING TISSUE** — Here is a wonderful Gov't. surplus buy of Lens Paper which was made to the highest Gov't. standards and specifications.

500 sheets size 7½" x 11"................. **$1.00**

## 3X TELESCOPE



Makes a nice low-priced finder. Brand new; has 1" Achromatic Objective. Amici Prism Erecting System, 1⅜" Achromatic Eye and Field Lens. Small, compact, wt. 2 lbs.

Gov't. Cost $200. **$9.75**

## FIRST-SURFACE MIRRORS

| Size | Thickness | Postpaid |
|---|---|---|
| 14" x 16" | ¼" | $10.00 |
| 8" x 10" | ¼" | 4.25 |
| 4" x 5" | ¼" | 1.85 |
| 4" x 4" | ¼" | 1.50 |
| 1¼" x 1½" | $\frac{1}{16}$" | .25 |

## RIGHT-ANGLE PRISMS

| | | | |
|---|---|---|---|
| 8 mm face.....ea. | $ .75 | 28 mm face.....ea. | $1.75 |
| 12 mm face.....ea. | .75 | 38 mm face.....ea. | 2.00 |
| 23 mm face.....ea. | 1.25 | 47 mm face.....ea. | 3.00 |

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